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Evaluating Sovereign Disaster Risk Finance Strategies: Case Studies and Guidance

UKaid from the British people
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Table of Contents

List of Tables

List of Figures

Overview

The cost of disasters to governments, households, and businesses is increasing. Population growth, increasing concentration of assets, and climate change are increasing exposure, hazards, and losses. Developing countries typically lack financial protection against the impacts of these disasters and rely on ex-post measures (for example, budget reallocations, donor assistance, tax increases, and post-disaster loans) to attempt to meet financing needs.

Disaster risk finance is an important component of the disaster risk management and climate change adaptation agenda. It aims to increase the financial resilience of countries against natural hazards by strengthening public financial management and promoting market-based disaster risk finance solutions (such as, sovereign catastrophe risk transfer solutions for governments or domestic catastrophe risk insurance markets for public and private assets).

However, when designing disaster risk finance solutions, details matter. Catastrophe risk data and information lay the ground for disaster risk finance solutions, but they need to be processed in order to inform financial decision making. Despite an increasing amount of disaster risk data made available from historical databases on disaster losses and catastrophe risk models, countries often lack the capacity, resources, and experience to properly analyze this information for informed financial decision making. Without such analysis governments do not have the quantitative tools to evaluate: (i) whether the proposed instrument would offer effective financial protection against natural disaster and how it would complement their existing strategy, if any, and (ii) whether the price of the proposed instrument is cost-effective compared to other financial options.

To respond to this, the Disaster Risk Finance Impact Analytics Project developed a comprehensive framework for assessing the costs[1] and benefits of the full range of budgetary and financial instruments available to governments and their development partners.[2] The framework covers such instruments as:

- Risk transfer instruments including insurance, reinsurance, catastrophe swaps, and catastrophe bonds
- Reserves / ex-ante budget allocations
- Contingent credit
- Emergency ex-post budget reallocations
- Ex-post direct credit (post-disaster debt).

This framework has been designed for governments and development partners to identify the most appropriate and financially efficient strategies to fund disaster losses, based on their country risk profile and political constraints. It uses the economic notion of opportunity cost to quantify the costs and benefits of alternative instruments for funding disaster-induced losses.

This report complements the more theoretical framework paper with a demonstration of how the framework can be applied in practice. Five case studies illustrate a range of questions that policy makers might ask, potential instruments to be considered, and economic conditions, and a Guidance Note presents principles for such analyses.

The structure of the report is as follows: the proposed framework is presented, outlining the approach of the opportunity-cost framework and its limitations. The five case studies are introduced and the contingent liability and finance strategies considered in each are outlined. Subsequently, the five case studies are presented in five chapters, each standalone with relevant annexes (including at the back of the report). Finally, a Guidance Note outlines how the framework may be applied in a practical manner to

1 Where there are references to costs, these refer to the opportunity cost of providing the payouts defined in the contingent liability through the various financing instruments.

2 Clarke, D. J., O. Mahul, R. Poulter, and T.-L. The. 2016. "Evaluating Sovereign Disaster Risk Finance Strategies: A Framework." Policy Research Working Paper, The World Bank Group, Washington DC.

another country's plans for the disaster risk financing of a contingent liability. Lastly, a Glossary is provided.

The purpose of the entire report is to illustrate how to apply the framework to a country-specific question. All formulae and calculations applied in these case studies follow those in the technical framework paper.[2] It does not aim to make any generalized conclusion about which finance mechanisms are cheapest or how disaster risk finance should be structured.

Introduction to Case Studies

In order to demonstrate this framework in a practical manner, this report presents five sample country case studies as in the table below. The case studies are based on real countries that are exposed to the perils described, but the countries have been anonymized. The finance strategies considered were selected to reflect questions that were being asked in the country at the time of writing.

The currency considered is US$ and all figures have been approximately converted to US$ at average 2015 exchange rates.

Limitations of the Analysis

The analysis makes multiple assumptions on disaster risk, economic environment, and risk transfer instruments, and focuses solely on a finance structure assuming perfect knowledge of a contingent liability and a mechanism to measure this contingent liability. The analysis is based on the framework presented in Clarke et al. (2016) and is also subject to the limitations of the framework.[3]

The analysis is based on information from various sources including World Bank country specialists and economic information available online. Generally speaking, this information was of a high quality and broadly sufficient for the present purposes. Information received was both quantitative (for example, modelled distribution of losses

Country	Contingent Liability Considered	Disaster Risk Finance Instruments Considered				
		Ex-ante reserve (reserve fund)	Ex-ante contingent credit (contingent credit)	Ex-ante risk transfer (insurance)	Ex-post budget reallocation (budget reallocations)	Ex-post debt (post-disaster debt)
Country V	Country-wide response costs due to drought	✓		✓	✓	✓
Country W	Country-wide response costs due to flood	✓	✓	✓		✓
Country X	Insured losses of two main crops in several areas due to multiple perils	✓		✓	✓	✓
Country Y	Insurance program covering public emergency losses in multiple regions of a country due to earthquake and tropical cyclone events			✓		
Country Z	Public losses (emergency and reconstruction) due to tropical cyclone events	✓	✓	✓	✓	✓

3 Clarke, D. J., O. Mahul, R. Poulter, and T.-L. Teh. 2016. "Evaluating Sovereign Disaster Risk Finance Strategies: A Framework." Policy Research Working Paper, The World Bank Group, Washington DC.

from a particular peril) and qualitative (such as, description of the potential insurance coverage that might be available in the country). Where possible and relevant, sensitivity analyzes on the assumptions resulting from this information have been performed.

While the analysis provides a sufficient basis for comparing the opportunity costs of financing instruments, its use has limitations, including:

1. *Dependence on assumptions*: Each case study involves multiple assumptions relating to the disaster risk faced, the economic environment, and the risk transfer instruments available.
2. *Limited to financial structure:* The analysis focuses only on evaluating the opportunity cost of alternative disaster risk finance strategies to finance a well-defined contingent liability. The analysis does not consider whether or not an investment should be made in the first place (that is, there may be wider political considerations such that a country is content to avoid planning and instead rely on aid from donors following any disaster; this is not considered in this report).
3. *Financial considerations only:* The focus is on the monetary comparisons only and does not consider other considerations that are more difficult to quantify, such as the degree to which the instrument supports or requires strong public financial management (for example, if a country holds a sizable reserve fund to cover the most extreme potential disasters, it may be at risk of being fully spent on a small disaster due to political considerations).
4. *Source of finance:* There is no discrimination on the source of the finance as this might come from the regional government, national government, or development partners. Only the total overall opportunity cost is considered.

Country V Case Study

0. Country V – Introduction

0.1. Country V is a country in Africa vulnerable to drought. The contingent liability considered is defined as follows:

- **Peril:** Drought
- **Country area:** Whole country
- **Contingent liability:** The costs associated with supporting vulnerable households in districts affected by drought.

0.2. The focus of the Country V case study is to consider the relative cost saving of different risk finance strategies to cover government expenditures to support drought-affected households. The contingent liability being considered for Country V arises from the financial costs of supporting the population that is estimated to have fallen below the poverty line as a result of drought.

0.3. This chapter is structured with results presented in the main body for three different strategies. First the chapter sets out the risk finance strategies under consideration (Section 1) and the base assumptions and approach used to assess the strategies (Section 2). Following that, the results in the base case scenario (Section 3) and sensitivity scenario (Section 4) are presented. Supporting diagrams and comments are included for the underlying contingent liability (Annex V1), the base case assumptions (Annex V2), and the sensitivity analysis (Annexes V3 and V4).

1. Country V – Risk Finance Strategies

1.1. The analysis for Country V looks at the cost of alternative finance strategies.

1.2. All of the finance strategies considered are assumed to sit on top of a reserve fund that is established to meet approximately the 1 in 1.3 year contingent liability[4] (a loss equal to US$50m). All strategies also assume that if the additional measure being considered is exhausted then post-disaster debt will be issued by Country V. The source of the funding has not been considered and the conclusions could apply to any combination of government or donor funding.

1.3. Table V1.1 outlines the three finance strategies considered for Country V.

Table V1.1 – Strategies Considered

Layer	Strategy A	Strategy B	Strategy C
First	Reserve fund	Reserve fund	Reserve fund
🡇	Post-disaster debt	Insurance	Budget reallocations
Last		Post-disaster debt	Post-disaster debt

4 A 1 in 1.3 year financing cost refers to the cost to finance a loss with a return period of 1.3 years, equivalent to a 77 percent probability of occurrence. See Glossary for further details.

2. Country V – Approach and Assumptions

Natural hazard assumptions

- A Pareto distribution has been fitted to the number of people falling below the poverty line as a result of drought.
- It is assumed that part of the population – those falling below the poverty line even in years of adequate rainfall – is covered by an existing social protection program. The contingent liability considers the costs of transitory poverty due to drought only.
- It is assumed that supporting an affected individual costs US$45 per person.
- From the fitted Pareto distribution, 5,000 drought events have been simulated.
- The simulated loss distribution is presented in Annex V1.

Economic and risk transfer assumptions

2.1. Key assumptions, base parameters, and sensitivity analysis performed are summarized in Table V2.1 below.

2.2. Further details on the sources of the base assumptions, as well as other parameters not material for sensitivity analysis, are outlined in Annex V2.

3. Country V – Base Case Scenario Results

3.1. This section outlines the total costs for the three strategies considered. Costs are shown at different return periods to highlight which strategies are cheapest at covering the average loss, loss events of a lower magnitude, and more extreme loss events. For the Country V case study, the cost of the three strategies over the following return periods are considered:

- On average
- 1 in 5 year return period
- 1 in 30 year return period.

Table V2.1 – Assumptions Summary - Base Parameters and Sensitivity Analysis

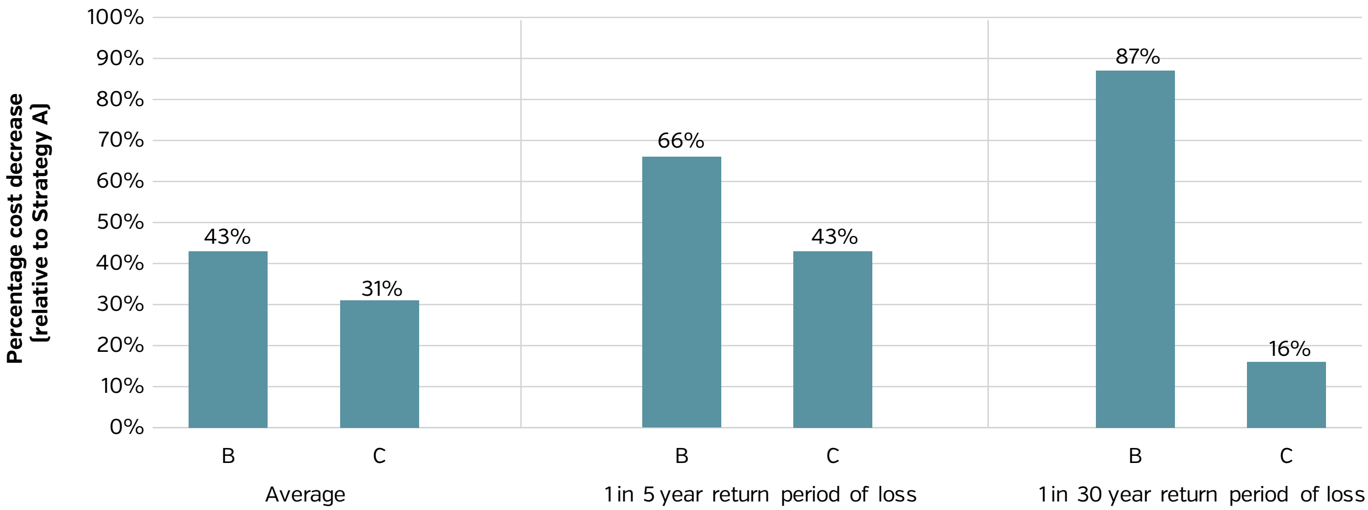
Assumption	Base Parameter	Sensitivity Analysis	Reference
Amount of reserve fund	US$50m	Increase to US$132m (which is the average expenditure)	Figure AV4.1 – Figure AV4.2
Spread between interest rate & investment return	3% (interest rate = 6.625%; investment return = 3.625%)	Increase the spread from 3% to 5% Reduce the spread from 3% to 1%	Figure AV3.2
Maximum insurance	1 in 30 year (US$433m)	Not considered	
Insurance pricing multiple	1.35	Increase the insurance pricing multiple from 1.35 to 2	Figure AV3.2
Maximum amount of budget reallocation	US$100m	Not considered	
Budget reallocation hurdle rate	10%	Increase to 20% and 40%	Figure AV3.3
Post-disaster debt delay factor	3 (US$1 now = US$3 post-event)	Reduce the delay factor from 3 to 1.5	Figure AV3.3
Contingent liability	Pareto distribution for the number of people falling below the poverty line as a result of drought	Loss distribution increased by 25% Loss distribution reduced by 25%	Figure AV4.3 – Figure AV4.6
Per person cost	US$45	Not considered	

3.2. Figure V3.1 presents the relative cost saving of Strategies B and C compared to Strategy A, under the base assumptions on average and at the 1 in 5 and 1 in 30 year return periods.

3.3. For example, on average across the 5,000 simulations, Strategy B is 43 percent cheaper than Strategy A.

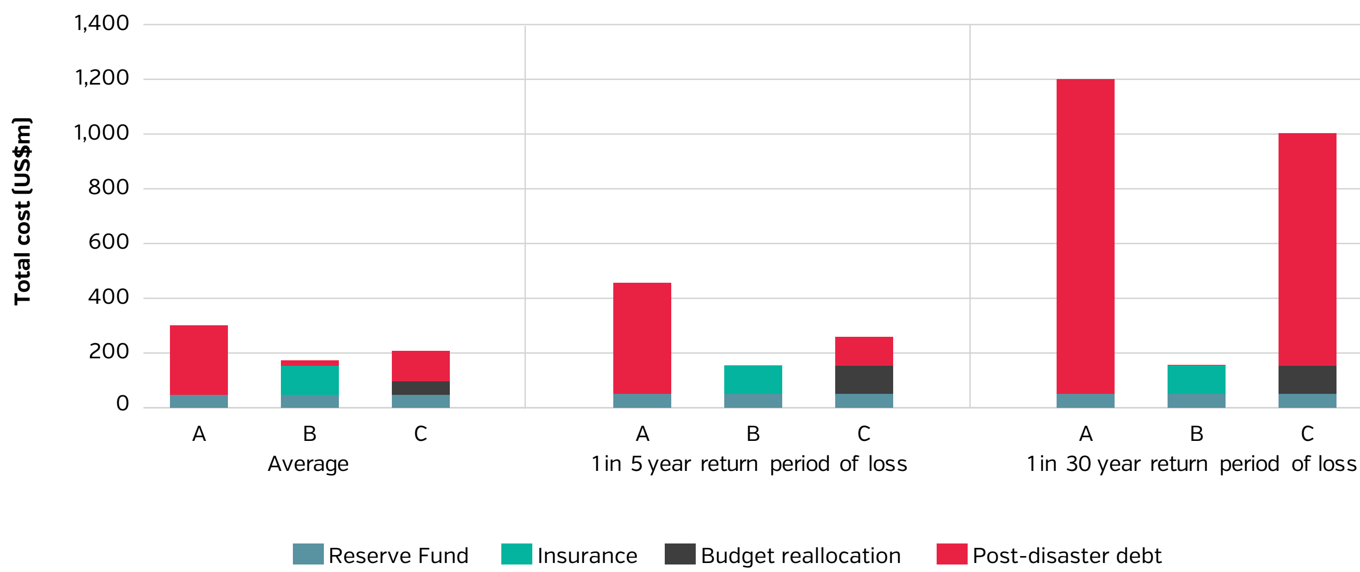
3.4. While Figure V3.1 compares the relative cost saving of the strategies at different return periods, it does not allow a direct comparison of the magnitude of the costs. Figure 3.2 shows the cost in monetary terms of the different strategies at the different return periods.

Figure V3.1 – Relative Cost Saving of Strategy B and C Compared to A



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Figure V3.2 – Cost of Finance Strategies, Base Case Assumptions



Source: Clarke, Cooney, Edwards, and Jinks (2016).

3.5. The main conclusions from the base case scenario as demonstrated in Figures V3.1 and V3.2 are:

- On average, Strategy B is the cheapest; insurance is more cost-effective than post-disaster debt due to the assumption of an insurance pricing multiple of 1.35 compared to a delay factor of 3.0 on post-disaster debt.
- On average, Strategy C is only marginally more expensive than Strategy B. This is because although the assumed budget reallocation hurdle rate of 10 percent is lower than the assumed insurance pricing multiple of 1.35, this is more than offset by the fact that budget reallocation is exhausted (at US$100m) at a lower level than insurance (at US$433m) and hence more expensive post-disaster debt covers more of the losses.
- Note that the costs at the 1 in 5 year period are higher than the average costs for all strategies. This is because the average loss under the assumed distribution is smaller than the 1 in 5 year loss. (See Annex V1 for the assumed distribution of losses.)
- At higher return periods, the costs of Strategy B are significantly lower than the costs of the other strategies as losses are passed onto the insurer.
- Strategy A always has the greatest cost due to the relatively higher post-disaster delay factor costs compared to other finance instruments.

4. Country V – Sensitivity Results

4.1. The Country V case study considers sensitivity analysis to:

- The economic and financial assumptions used to derive the costs of the strategies
- The maximum amount of losses covered by the different finance strategies.

Sensitivity Results: Varying the Economic and Financial Assumptions

4.2. A marginal cost analysis for each finance instrument is used to demonstrate their features and benefits over varying return periods. The marginal cost analysis in Annex V3 demonstrates the intuitive notion that as the economic cost of a finance source increases, the attractiveness of that source decreases, namely:

- Reserve funds are marginally the cheapest finance instrument up to approximately the 1 in 2.1 year return period.
- After the 1 in 2.1 year return period, budget reallocation becomes the cheapest instrument. However, the marginal cost analysis ignores that there might be a limit on the extent to which government budgets can be reallocated.

4.3. The results indicated by the marginal costs analysis are dependent on the financial and other assumptions selected. If these assumptions are varied, the outcomes can be materially different. Sensitivity to economic parameters for each of these finance instruments is also demonstrated in Annex V3. The results vary intuitively as the economic parameters are adjusted and the following can be noted:

- Increasing the assumed budget reallocation hurdle rate reduces the cost benefit of budget reallocation.
- Similarly, increasing the insurance pricing multiple decreases the cost benefit gained from insurance.
- Adjusting the delay factor downward makes post-disaster debt more attractive.
- Increasing the spread between the investment and borrowing rates increases the marginal cost of the reserves as it increases the cost of holding reserve funds that may not be called on.

Sensitivity Results: Varying Maximum Funding by Finance Instrument

4.4. The results shown in the base case scenario are dependent on the amount of funding assumed to be available by each finance instrument and the assumed loss distribution. Sensitivity to the size of the reserve fund layer and underlying loss distribution is demonstrated through examination of the total cost analysis. The results vary intuitively with the following key results (see Annex V4 for details):

- Increasing the size of the reserve fund decreases the costs of all strategies as more losses are met by the reserve fund, which is the most cost-effective strategy at lower return periods.
- Increasing the assumed losses increases the costs of all strategies. It also reduces the cost-effectiveness of the strategies if the size of the layers are unchanged.
- Decreasing the assumed losses reduces the costs of all strategies. It also increases the cost-effectiveness of Strategies A and C as more losses are covered by the reserve fund.

5. Country V – Concluding Remarks

5.1. The most cost-effective strategy will depend on the risk tolerance of policy makers. The analysis shows that when considering drought events, losses that are of a lower impact and occur more frequently are likely to be most cost-effectively financed by holding a reserve fund and reallocating from existing budgets.

5.2. Given the likely limitations on the amount of the reserve fund and the budget reallocation that will be available, insurance is a cost-effective alternative. Insurance may result in an overall cheaper strategy as although it is marginally more expensive at lower return periods, it can likely cover a greater layer of loss before the most expensive post-disaster debt finance kicks in.

5.3. Additionally, strategies involving insurance are likely to be attractive at the higher return periods when losses are ceded to the insurer.

Country W Case Study

0. Country W – Introduction

0.1. Country W is a country in Africa vulnerable to flood. The contingent liability considered is defined as follows:

- **Perils:** Flood
- **Country area:** Majority of the regions in the country
- **Contingent liability:** Planned Government social protection expenditures to support flood-affected households.

0.2. The focus of the Country W case study is to consider the relative cost saving of different risk finance strategies to cover government expenditures to support flood-affected households. The contingent liability being considered for Country W arises from the financial costs of social protection transfers to flood-affected households.

0.3. This chapter is structured with results presented in the main body for three different strategies. First the report sets out the risk finance strategies under consideration (Section 1) and the base assumptions and approach used to assess the strategies (Section 2). Following that, the results in the base case scenario (Section 3) and sensitivity scenario (Section 4) are presented. Supporting diagrams and comments are included for the underlying contingent liability (Annex W1), the base case assumptions (Annex W2) and the sensitivity analysis (Annexes W3 and W4).

1. Country W – Risk Finance Strategies

1.1. The analysis for Country W looks at the cost of alternative finance strategies.

1.2. All of the finance strategies considered are assumed to sit on top of a reserve fund that is established to meet approximately the 1 in 2.3 year contingent liability (a loss equal to US$100m). All strategies assume that if the additional finacial instrument being considered is exhausted then post-disaster debt will be issued by Country W. The source of the funding has not been considered and the conclusions could apply to any combination of government or donor funding.

1.3. Table W1.1 outlines the three finance strategies considered for Country W.

2. Country W – Approach and Assumptions

Natural hazard assumptions

- Based on over 30 years of historic data of the number of people in poverty due to flood.
- Approximately 25 percent of historical years showed no-one affected by flood. A 25 percent probability of nobody being affected by flood is therefore assumed.

Table W1.1 – Strategies Considered

Layer	Strategy A	Strategy B	Strategy C
First	Reserve fund	Reserve fund	Reserve fund
↓	Post-disaster debt	Insurance	Contingent credit
Last		Post-disaster debt	Post-disaster debt

- The remaining 75 percent of historical years have been fitted to an exponential distribution with mean of 1.8m people affected (that is, when there is a flood, on average 1.8m people are affected with flood events following an exponential distribution).
- Combining the years in which people are affected and the years in which no-one is affected, the total mean number of people in poverty is 1.35m. Monetary losses are derived by multiplying the assumed number of people affected by a per person cost of US$100.
- The fit to the data is demonstrated in Annex W1.

Economic and risk transfer assumptions

2.1. Key assumptions, base parameters, and sensitivity analysis performed are summarized in Table W2.1.

2.2. Further details on the sources of the base assumptions, as well as other parameters not material for sensitivity analysis, are outlined in Annex W2.

3. Country W – Base Case Scenario Results

3.1. This section outlines the total costs for the three strategies considered. Costs are shown at different return periods, to highlight which strategies are cheapest at covering the average loss, loss events of a lower magnitude, and more extreme loss events. For the Country W case study, the cost of the three strategies over the following return periods are considered:

Table W2.1 – Assumptions Summary, Base Parameters and Sensitivity Analysis

Assumption	Base Parameter	Sensitivity Analysis	Reference
Amount of reserve available	US$100m	Increase to US$150m	Figure AW4.3 – AW4.4
Spread between interest rate & investment return	10% (interest rate = 13%; investment return = 3%)	Increase the spread from 10% to 15% Decrease the spread from 10% to 5%	Figure AW3.2
Amount of contingent credit available	US$100m	Increase to US$150m	Figure AW4.3 – AW4.4
Contingent credit interest rate	2.5%	Increase to 5%	Figure AW3.2
Contingent credit facility arrangement fee	0.5% of maximum loan amount	Not considered	
Maximum insurance	1 in 30 (US$559m)	Not considered	
Proportion of losses ceded to insurance	100%	Decrease to 50% (with remainder covered by post-disaster debt)	Figure AW4.1 – AW4.2
Insurance pricing multiple	1.5	Increase the insurance pricing multiple from 1.5 to 2	Figure AW3.3
Post-disaster debt delay factor	3 (US$1 now = US$3 post-event)	Reduce the delay factor from 3 to 1.4	Figure AW3.3
Contingent liability	Exponential distribution for the number of people affected by flood	Not considered	
Per person cost	US$100	Not considered	

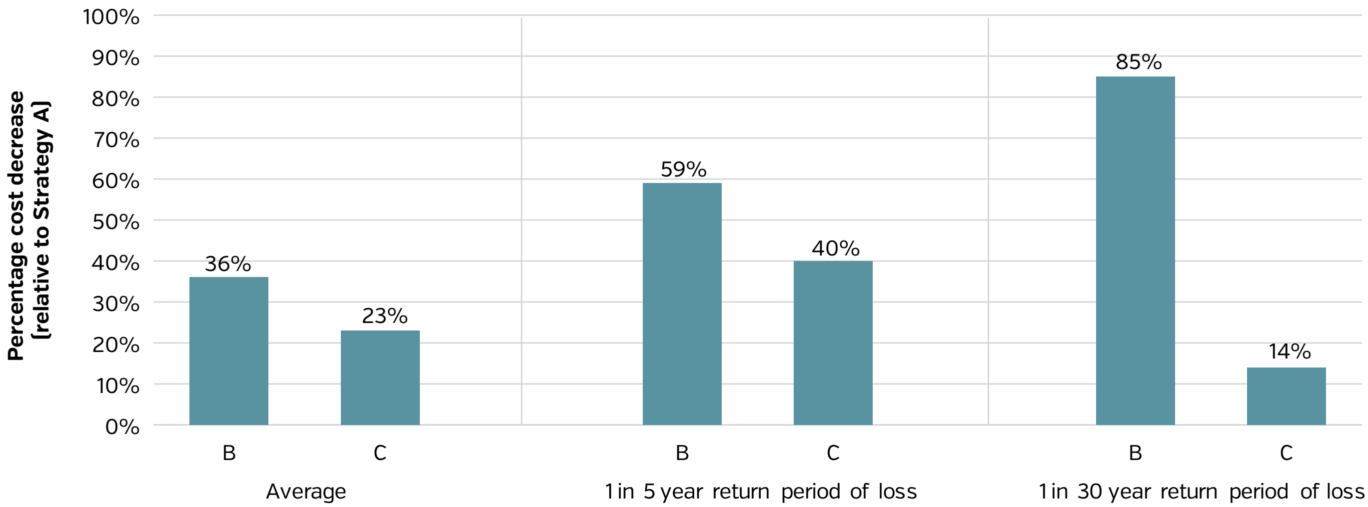
- On average
- 1 in 5 year return period
- 1 in 30 year return period.

3.2. Figure W3.1 presents the relative cost saving of Strategies B and C compared to Strategy A, under the base assumptions on average and at the 1 in 5 and 1 in 30 year return periods.

3.3. While Figure W3.1 compares the relative cost saving of the strategies at different return periods, it does not allow a direct comparison of the magnitude of the costs. Figure W3.2 shows the cost, in monetary terms of the different strategies at the different return periods.

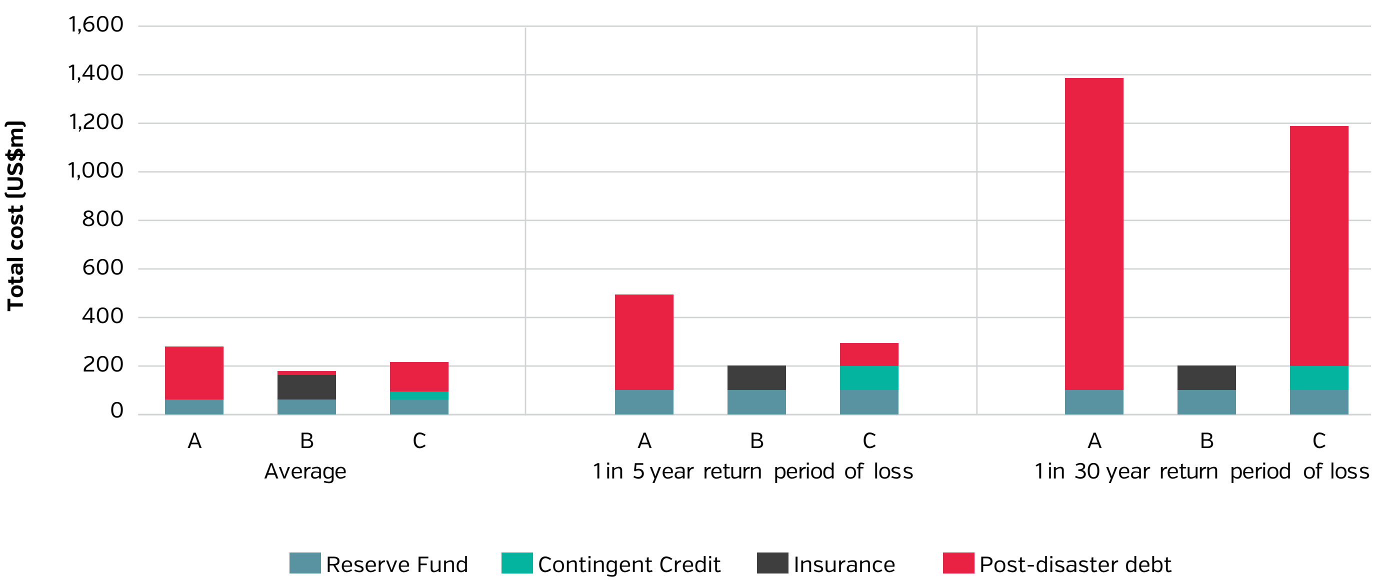
3.4. The main conclusions from the base case scenario as demonstrated in Figures W3.1 and W3.2 are:

Figure W3.1 – Relative Cost Saving of Strategy B and C compared to A



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Figure W3.2 – Cost of Finance Strategies, Base Case Assumptions



Source: Clarke, Cooney, Edwards, and Jinks (2016).

- On average, Strategy B is the cheapest; insurance is more cost-effective than post-disaster debt due to the assumption of an insurance pricing multiple of 1.5 compared to a delay factor of 3 on post-disaster debt.
- Strategy C, although including contingent credit financing which at lower return periods is more cost-effective than insurance, is not cheaper than Strategy B because contingent credit covers only a relatively small amount of loss. The remainder is financed by post-disaster debt, which drives the overall cost of Strategy C.
- Note that the costs at the 1 in 5 year period are higher than the average costs for all strategies. This is because the average loss under the assumed distribution is smaller than the 1 in 5 year loss (see Annex W1 for the assumed distribution of losses).
- At higher return periods, the costs of Strategy B are significantly lower than the costs of the other strategies as finance costs are passed onto the insurer.
- Strategy A always has the greatest cost due to the relatively higher post-disaster delay factor costs compared to other finance instruments.

4. Country W – Sensitivity Results

4.1. The Country W case study considers sensitivity analysis to:

- The economic and financial assumptions used to derive the costs of the strategies
- The maximum amount of losses covered by the different finance strategies.

Sensitivity Results: Varying the Economic and Financial Assumptions

4.2. A marginal cost analysis for each finance instrument is used to demonstrate their features and benefits over varying return periods. The marginal cost analysis in Annex W3 demonstrates the intuitive notion that as the economic cost of a finance source increases, the attractiveness of that source decreases, namely:

Reserves are marginally the cheapest finance instrument (though contingent credit is only very marginally more expensive) up to approximately the 1 in 7 year return period, after which insurance becomes the cheapest instrument.

4.3. The results indicated by the marginal costs analysis are dependent on the financial and other assumptions selected. If these assumptions are varied the outcomes can be materially different. Sensitivity to economic parameters for each of these finance instruments is also demonstrated in Annex W3.The results vary intuitively as the economic parameters are adjusted and the following can be noted:

- Increasing the insurance pricing multiple decreases the cost benefit gained from insurance.
- Adjusting the post-disaster debt delay factor downward makes post-disaster debt more attractive.
- Increasing the spread between the investment and borrowing rates increases the marginal cost of the reserves as it increases the cost of holding reserve funds which may not be called on.
- Similarly, increasing the interest rate charged on contingent credit reduces the cost benefit of the contingent credit.

Sensitivity Results: Varying Maximum Funding by Finance Instrument

4.4. The results shown in the base case scenario are dependent on the amount of funding assumed to be available by each finance instrument. Sensitivity to the size of the layers is demonstrated through examination of the total cost analysis. The results (see Annex W4 for details) vary intuitively as the amounts available from each finance instruments are adjusted, with the following key results:

- Decreasing the percentage of loss covered by insurance demonstrates that on average Strategy C, which includes contingent credit, is the cheapest. This is due to the fact that the proportion in Strategy B not ceded to insurance is covered by the more costly post-disaster debt.
- Increasing the amount of financing available from reserves and contingent credit reduces the cost savings of Strategies B and C (relative to Strategy A) because more loses are met by reserves and contingent credit which are both cheaper than post-disaster debt.

5. Country W – Concluding Remarks

5.1. The most cost-effective strategy will depend on the risk tolerance of policy makers. The analysis shows that when considering flood events, losses that are of a lower impact and occur more frequently are likely to be most cost-effectively financed by holding reserves and contingent credit.

5.2. Given the likely limitations on the amount of reserves and contingent credit that will be available, insurance is a cost-effective alternative. Insurance may result in an overall cheaper strategy as although it is marginally more expensive at lower return periods, it is assumed to cover a greater layer of loss before the most expensive post-disaster debt finance kicks in.

5.3. Additionally, strategies involving insurance are likely to be attractive at the higher return periods when losses are ceded to the insurer.

Country X Case Study

0. Country X – Introduction

0.1. Country X is a country in Asia vulnerable to flood, drought, and other perils. The contingent liability considered is defined as follows:

- **Perils:** All natural perils affecting maize crops (flood, drought, tropical cyclone, pests)
- **Country area:** Three regions of the country (covering less than 5 percent of the country's population) that are vulnerable to several perils and rely heavily on the yield from maize produced in the regions
- **Contingent liability:** Insured losses (in US$) due to a reduction in yield from crop failure for two maize varieties.

0.2. The focus of the Country X case study is to consider the relative cost saving of different risk finance strategies to cover the insured losses from publicly-supported maize insurance policies. The contingent liability being considered for Country X arises from the money that would be required if crop losses triggered insurance payouts.

0.3. This chapter is structured with results presented in the main body for three different strategies. First the chapter sets out the risk finance strategies under consideration (Section 1) and the base assumptions and approach used to assess the strategies (Section 2). Following that, the results in the base case scenario (Section 3) and sensitivity scenario (Section 4) are presented. Supporting diagrams and comments are included for the underlying contingent liability (Annex X1), the base case assumptions (Annex X2) and the sensitivity analysis (Annexes X3 and X4).

1. Country X – Risk Finance Strategies

1.1. The analysis for Country X looks at the cost of alternative finance strategies.

1.2. All of the finance strategies considered are assumed to sit on top of a reserve fund that is established to meet approximately the 1 in 2.5 year contingent liability (a loss equal to US$20m). All strategies also assume that if the additional measure being considered is exhausted then post-disaster debt will be issued by Country X. The source of the funding has not been considered and the conclusions could apply to any combination of government or donor funding.

1.3. Table X1.1 outlines the three finance strategies considered for Country X.

Table X1.1 – Strategies Considered

Layer	Strategy A	Strategy B	Strategy C
First	Reserve fund	Reserve fund	Reserve fund
⬇	Post-disaster debt	Insurance	Budget reallocations
Last		Post-disaster debt	Post-disaster debt

2. Country X – Approach and Assumptions

Natural hazard assumptions

- Based on a third party model, which simulates the reduction in maize yields caused by all perils.
- Yields are projected in the local currency for two types of maize in each of the three regions considered.
- The distribution is based on 5,000 simulations of yield loss.
- The corresponding yield loss cost is converted to US$ using average recent exchange rates.
- The simulated loss distribution is demonstrated in Annex X1.

Economic and risk transfer assumptions

2.1. Key assumptions, base parameters, and sensitivity analysis performed are summarized in Table X2.1 below:

2.2. Further details on the sources of the base assumptions, as well as other parameters not material for sensitivity analysis, are outlined in Annex X2.

3. Country X – Base Case Scenario Results

3.1. This section outlines the total costs for the three strategies considered. Costs are shown at different return periods, to highlight which strategies are cheapest at covering the average loss, loss events of a lower magnitude, and more extreme loss events. For the Country X case study, the cost of the three strategies outlined above over the following return periods are considered:

- On average
- 1 in 5 year return period
- 1 in 30 year return period.

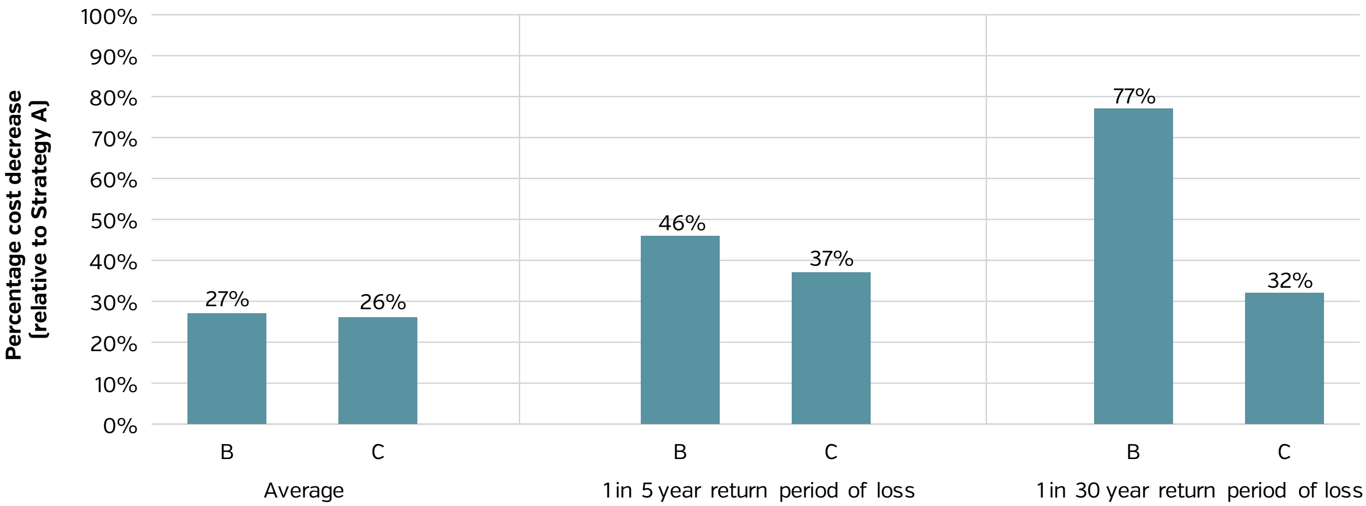
3.2. Figure X3.1 presents the relative cost savings of Strategies B and C compared to Strategy A, under the base assumptions.

3.3. While Figure X3.1 compares the relative cost saving of the strategies at different return periods, it does not allow a direct comparison of the magnitude of the costs. Figure X3.2 shows the cost, in monetary terms of the different strategies at the different return periods.

Table X2.1 – Assumptions Summary, Base Parameters and Sensitivity Analysis

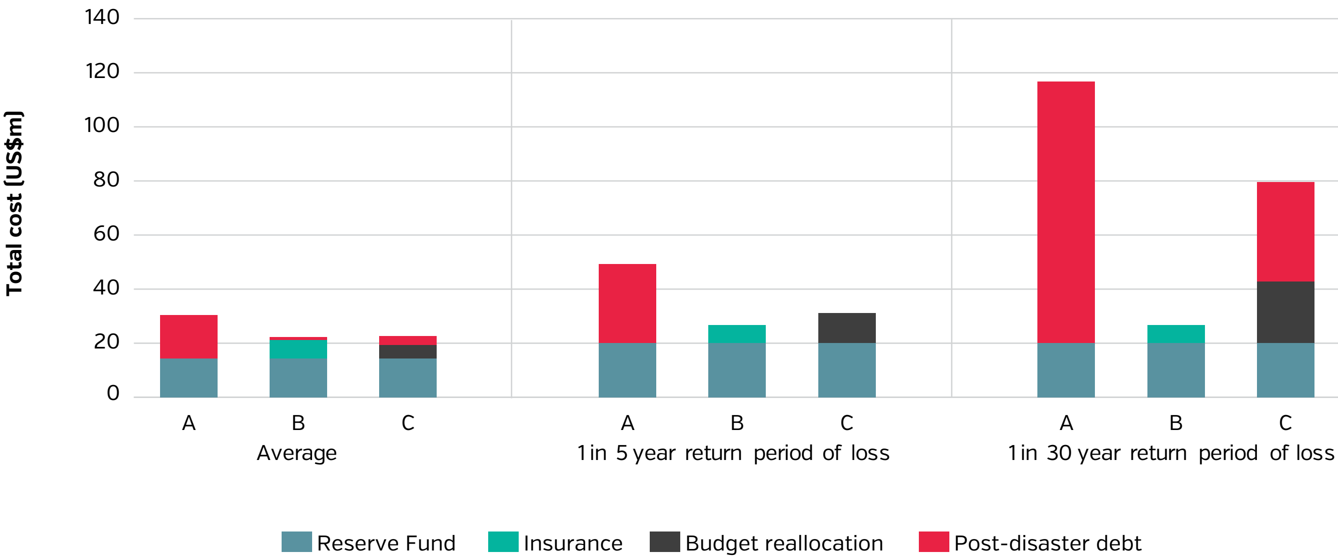
Assumption	Base Parameter	Sensitivity Analysis	Reference
Amount of reserve available	US$20m	Decrease to US$10m Increase to US$30m	Figure AX4.1 – Figure AX4.4
Spread between interest rate & investment return	2% (interest rate = 5%; investment return = 3%)	Increase the spread from 2% to 4%	Figure AX3.2
Maximum insurance	1 in 30 (US$52.4m)	Not considered	
Insurance pricing multiple	1.35	Increase the insurance pricing multiple from 1.35 to 2	Figure AX3.3
Amount of budget reallocation	US$20m	Not considered	
Budget reallocation hurdle rate	20%	Decrease to 10% Increase to 40%	Figure AX3.2
Post-disaster debt delay factor	3 (US$1 now = US$3 post-event)	Increase the delay factor from 3 to 5 Reduce the delay factor from 3 to 1.5	Figure AX3.3
Contingent liability	Third party model of reduction in maize yields	Not considered	

Figure X3 .1 – Relative Cost Saving of Strategy B and C Compared to A



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Figure X3.2 – Cost of Finance Strategies, Base Case Assumptions



Source: Clarke, Cooney, Edwards, and Jinks (2016).

3.4. The main conclusions from the base case scenario as demonstrated in Figures X3.1 and X3.2 are:

- On average, Strategy B is the cheapest; insurance is more cost-effective than post-disaster debt due to the assumption of an insurance pricing multiple of 1.35 compared to a delay factor of 3.0 on post-disaster debt.
- On average, Strategy C is only marginally more expensive than Strategy B. This is because although the assumed hurdle rate of 20 percent is lower than the assumed insurance pricing multiple of 1.35, this is more than offset by the fact that budget reallocation is exhausted (at US$40m) at a lower level than insurance (at US$52.4m) and hence more expensive post-disaster debt covers more of the losses.
- Note that the costs at the 1 in 5 year period are higher than the average costs for all strategies. This is because the average loss under the assumed distribution is smaller than the 1 in 5 year loss (see Annex X1 for the assumed distribution of losses).
- At higher return periods, the costs of Strategy B are significantly lower than the costs of the other strategies as finance costs are passed onto the insurer.
- Strategy A always has the greatest cost due to the relatively higher post-disaster delay factor costs compared to other finance instruments.

4. Country X – Sensitivity Results

4.1. The Country X case study considers sensitivity analysis to:

- The economic and financial assumptions used to derive the costs of the strategies
- The maximum amount of losses covered by the different finance strategies.

Sensitivity Results: Varying the Economic and Financial Assumptions

4.2. A marginal cost analysis for each finance instrument is used to demonstrate their features and benefits over varying return periods. The marginal cost analysis in Annex X3 demonstrates the intuitive notion that as the economic cost of a finance source increases, the attractiveness of that source decreases, namely:

- Reserves are marginally the cheapest finance instrument up to approximately the 1 in 8.5 year return period.
- After the 1 in 8.5 year return period, budget reallocation becomes the cheapest instrument. However, the marginal cost analysis ignores that there might be a limit on the extent to which government budgets can be reallocated.

4.3. The results indicated by the marginal costs analysis are dependent on the financial and other assumptions selected. If these assumptions are varied, the outcomes can be materially different. Sensitivity to economic parameters for each of these finance instruments is also demonstrated in Annex X3. The results vary intuitively as the economic parameters are adjusted and the following can be noted:

- Increasing the assumed hurdle rate for budget reallocation reduces the cost benefit of budget reallocation.
- Similarly, increasing the insurance pricing multiple decreases the cost benefit gained from insurance.
- Adjusting the delay factor downward makes post-disaster debt more attractive.
- Increasing the spread between the investment and borrowing rates increases the marginal cost of the reserves as it increases the cost of holding reserve funds which may not be called on.

Sensitivity Results: Varying Maximum Funding by Finance Instrument

4.4. The results shown in the base case scenario are dependent on the amount of funding assumed to be available by each finance instrument. Sensitivity to the size of the reserve layer is demonstrated through examination of the total cost analysis. The results (see Annex X4 for details) vary intuitively as the reserve is adjusted, with the following key results:

- Decreasing the size of the reserve fund increases the costs of all strategies as fewer losses are met by the reserves which is the most cost-effective strategy at lower return periods.
- Increasing the size of the reserve fund decreases the costs of all strategies as more losses are met by the reserves, and is the most cost-effective strategy at lower return periods. If the reserve is increased to US$30m then Strategy A becomes the cheapest strategy at lower return periods.

5. Country X – Concluding Remarks

5.1. The most cost-effective strategy will depend on the risk tolerance of policy makers. The analysis shows that when considering maize losses due to multiple perils, losses which are of a lower impact and occur more frequently are likely to be most cost-effectively financed by holding reserves.

5.2. Budget reallocation is assumed to have the lowest marginal cost at the higher loss events. However, there may be a limit on the extent to which government budgets can be reallocated. As a result, strategies involving insurance are likely to be attractive, particularly at the higher return periods when losses are ceded to the insurer.

Country Y Case Study

0. Country Y – Introduction

0.1. Country Y is a country with a large diversified economy and has regions that have very high recurrent risk of disasters from both earthquakes and tropical cyclones.

0.2. Thirteen regions in Country Y are assumed to have selected parametric insurance coverage for earthquake and tropical cyclone risk, with claim payments based on modelled loss, as determined by a pre-agreed catastrophe risk model.

0.3. The focus of the Country Y case study is to evaluate the costs of potential disaster risk finance structures that could provide the desired insurance coverage, where regions either act independently or work together in different ways.

0.4. This case study is structured with results presented in the main body for two main scenarios – the base case scenario and the sensitivity scenario. The case study is structured as follows. First the risk finance strategies (Section 1) and relevant assumptions (Section 2) are outlined. Then the results in the base case scenario (Section 3) and sensitivity scenario (Section 4) are presented. Supporting diagrams and comments are included for the underlying contingent liability (Annex Y1), the base case assumptions (Annex Y2) and the sensitivity analysis (Annex Y3).

1. Country Y – Risk Finance Strategies

1.1. The analysis for Country Y looks at the cost of financing regional insurance policies through alternative insurance placement arrangements (see Table Y1.1). The underlying insurance contracts are parametric in nature with insurance premiums and payouts defined through a catastrophe risk model as a function of wind speed (tropical cyclone coverage) and ground acceleration (earthquake coverage). The model has been designed to try to proxy emergency losses incurred by the government in the local regions.

Insurance payouts

- The insurance contract has a two-step payout function with defined partial and full payouts.
- The attachment point (trigger point) for partial payouts is the 1 in 10 year emergency loss. Partial payouts are assumed to be US$16m across tropical cyclone and earthquake (allocated either US$8m/$8m if the risk of losses from each peril is considered roughly equal or US$12m/$4m if the region is more vulnerable to tropical cyclone).
- The attachment point for full payouts is the 1 in 30 year emergency loss. Full payouts are assumed to be US$40m across tropical cyclone and earthquake (allocated either US$20m/$20m or US$30m/$10m under the same rationale as the partial payouts.
- More than 1 partial payout can be made in a year subject to a maximum annual payout equal to the full payout.

1.2. The contingent liability considered in the opportunity cost analysis are the cumulative insurance payouts (or costs) for all individual insurance policies (for the 13 regions) as defined above.

1.3. Three alternative insurance placement arrangements with different pooling mechanisms were considered as outlined in Table Y1.1.

Table Y1.1 – Strategies Considered

Insurance Strategy A	Insurance Strategy B	Insurance Strategy C
Individual insurance contracts for each region.	Regions jointly approach the reinsurance market with a portfolio of region-specific insurance policies.	**Regional Insurance Facility** Regions establish a catastrophe risk insurance facility, acting as a joint reserve mechanism, where smaller payouts are retained through reserves and excess losses are transferred to the reinsurance market. **Retention level (smaller losses)** Up to first 1 in 10 year aggregate loss of the portfolio **Reinsurance (excess losses)** All losses beyond the 1 in 10 year aggregate loss of the portfolio

2. Country Y – Approach and Assumptions

Natural hazard assumptions

2.1. The analysis is based on 10,000 simulated years of emergency losses caused by tropical cyclone and earthquake events across 13 regions, many of which years have multiple events. On average, there are a total of 3.4 events per year per region. The average tropical cyclone impacts 3.8 regions and the average earthquake impacts 2.1 regions.

2.2. The base case scenario assumptions and sensitivity analysis performed on these are outlined below in Table 2.1, with supporting detail in Annex Y2. All sensitivity analyses are presented in section 4 with supporting detail in Annex Y3.

Table Y2.1 – Assumptions Summary, Base Parameters and Sensitivity Analysis

Assumption	Base Parameter	Sensitivity Analysis
Strategy A pricing multiple	1.64	N/A
Strategy B pricing multiple	1.47 (= 90% * 1.64) where there is a 10% diversification benefit compared to Strategy A	1.31 (= 80% * 1.64) where there is a 20% diversification benefit compared to Strategy A
Strategy C Pricing multiple (paid for excess losses above the first 1 in 10 year event in a year for Strategy C)	2.0	Decrease to 1.47 for comparison against Strategy B
Spread between interest rate & investment return	0% (interest rate = 4%; investment return = 4%)	Increase the spread from 0% to 5%

3. Country Y – Base Case Scenario Results

3.1. Figure Y3.1 presents the costs of the three risk transfer strategies at various return periods in the base case scenario assumptions.

3.2. The cost of Strategy B is always lower than Strategy A, due to the diversification benefit in Strategy B. Strategy A and B have all underlying assumptions identical except Strategy B has a diversification benefit of 10 percent (decreasing the cost) and a market fee of 2.5 percent (increasing the cost). The result is a constant net decrease at all return periods in the cost of Strategy B compared to Strategy A.

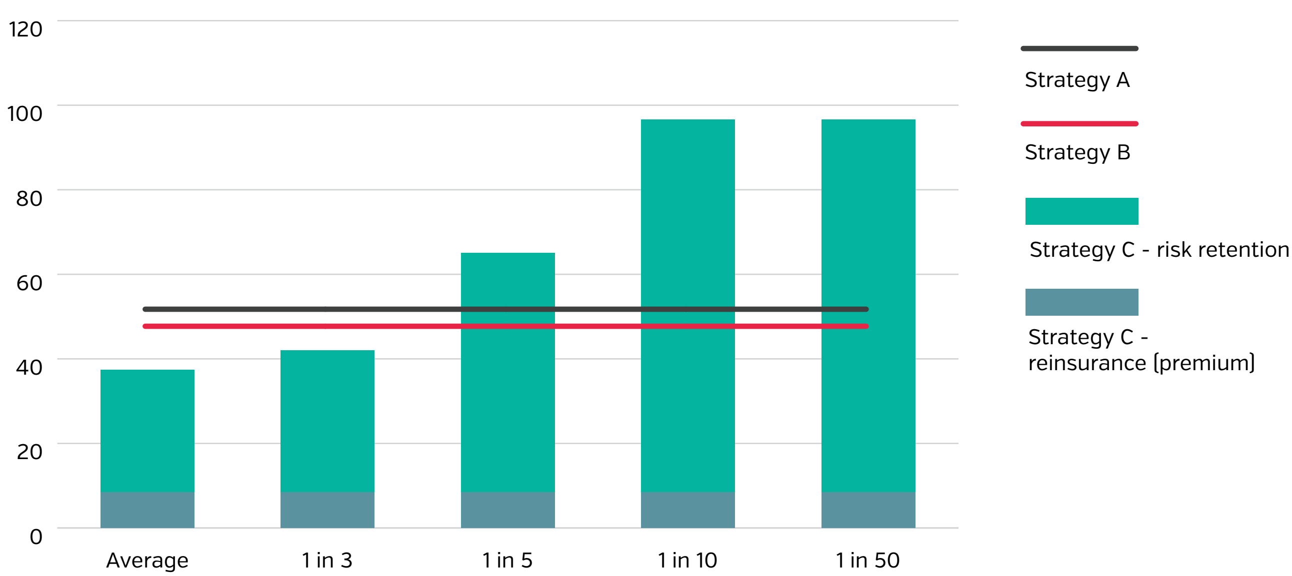
3.3. The cost of Strategy C is driven by the cost of risk retention. In the base case scenario, there is no foregone investment return on reserve funds held since the investment return is assumed to be equal to the discount rate, and the cost of financing the retained payouts is equal to the retained payouts themselves at all return periods:

- On average, the cost of Strategy C is lower than Strategy A and B. This is because on average, it is cheaper to finance the cost of the relevant payouts through a reserve fund (with no charge applied) than to pay a pricing premium (through a pricing multiple) for insurance placement.
- For greater payouts at the 1 in 5 year return and beyond, the cost of Strategy C becomes higher than Strategy A and B, since the payouts retained increase and have to be financed by the reserve funds.
- Beyond the 1 in 10 year return period, Strategy C cost levels off because only up to the 1 in 10 year payout is retained in the reserve fund, as defined in the mechanism for Strategy C.

4. Country Y – Sensitivity Results

4.1. Figure Y4.1 presents the costs of the three risk transfer strategies at various return periods in the base case scenario, as well as the following sensitivity scenarios:

Figure Y3.1 – Costs of Risk Transfer Strategies, Base Case Scenario Assumptions



Source: Clarke, Cooney, Edwards, and Jinks (2016).

- Increasing the Strategy B diversification benefit from 10 percent to 20 percent
- Reducing the Strategy C pricing multiple from 2.0 to 1.47
- Increasing the spread (between the interest rate and investment return) from 0 percent to 5 percent for Strategy C retained risk.

4.2. Annex Y3 outlines the rationale for selecting these sensitivities and presents the resulting diagnostics (pricing multiples and risk volatility factors) for each strategy as a comparison.

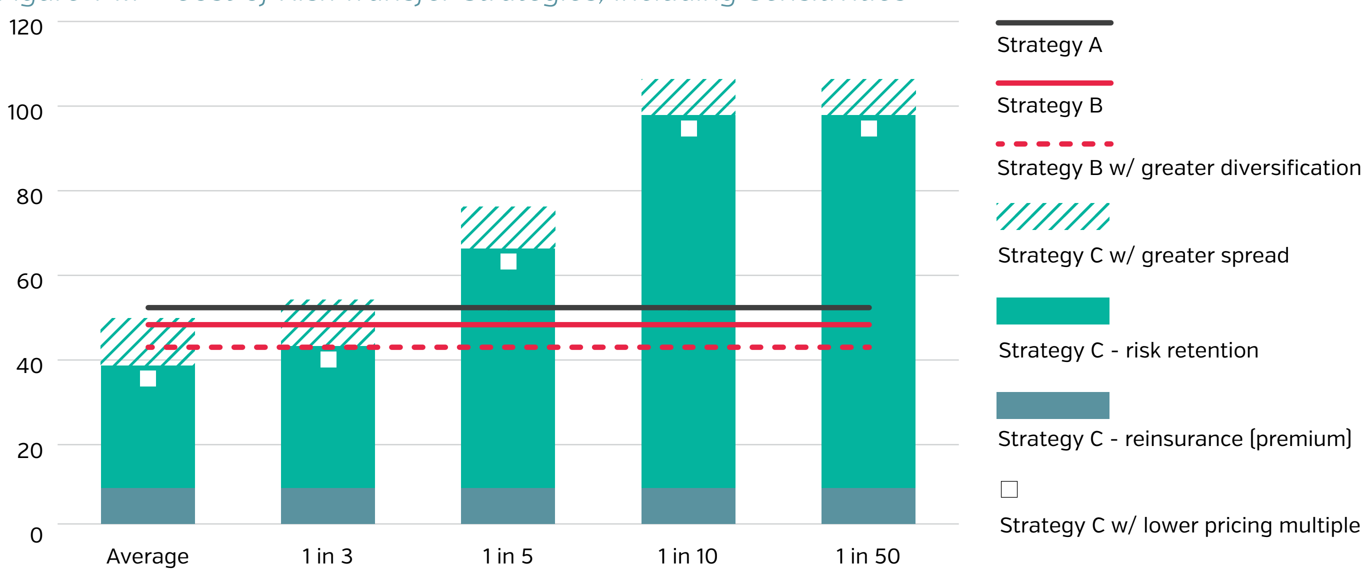
4.3. On average, Strategy C is the cheapest strategy if the spread between the investment return and discount rate is kept minimal. This is consistent with the conclusions in the base case scenario, where on average it is cheaper to finance the cost of the relevant payouts through a reserve fund (with no charge applied) than to pay a pricing premium (through a pricing multiple) for insurance placement. However, when a spread is introduced such that there is a charge on the reserves held, Strategy C becomes more expensive than Strategy B.

4.4. For payouts at the 1 in 3 year return period, the results are dependent on the sensitivities:

- Strategy C is again the cheapest if the spread between investment return and discount rate is zero, but Strategy B with a greater diversification benefit is only marginally more expensive.
- If Strategy C is considered with a greater spread (of 5 percent), then it becomes the most expensive, with a greater cost than Strategy A and B.

4.5. For higher payouts at or greater than the 1 in 5 year return period, Strategy B with a greater diversification benefit has a significantly cheaper cost than any other strategy. A summary of the cheapest, second cheapest, and most expensive strategies is presented in Table Y4.2.

Figure Y4.1 – Cost of Risk Transfer Strategies, Including Sensitivities



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Table Y4.2 – Sensitivity Analysis: Cheapest and Most Expensive Strategies by Return Period

	Average	1 in 3	1 in 5 and greater
Strategy A	Most expensive		
Strategy B			Second cheapest
Strategy B w/ greater diversification		Only marginally more expensive than Strategy C	**Cheapest**
Strategy C	Second cheapest	Second cheapest	Overall Strategy C is more expensive than Strategy A and B beyond the 1 in 5 year return period, under all sensitivities considered
Strategy C w/ lower pricing multiple	**Cheapest**	**Cheapest**	
Strategy C w/ greater spread		Most expensive	

Source: Clarke, Cooney, Edwards, and Jinks (2016).

5. Country Y – Concluding Remarks

5.1. Strategy C, which includes a portion of risk retention, is cheapest on average due to the low or non-existent cost charge on the reserves required to fund the retained level of payout (compared to the pricing premium charge of placing insurance coverage).

5.2. The greater the diversification benefit that can be achieved in Strategy B and the greater the charge (spread) on the reserves held for Strategy C, the lower the payouts at which Strategy B will become the most cost-effective strategy. This likely happens at some point between payouts at the 1 in 3 year and the 1 in 5 year return period.

5.3. The most cost-effective strategy will depend on the risk tolerance of policy makers. If the focus is on losses at lower return periods, or a long-term average cost, retaining a layer of payouts as in Strategy C may be the optimal choice. For increasingly greater payouts and when considering catastrophic tail risk, Strategy B is likely the most cost-effective strategy beyond the 1 in 5 year payout.

Country Z Case Study

0. Country Z – Introduction

- Country Z is a small island developing state, with the entire country vulnerable to the damage caused by tropical cyclones.
- The focus of the Country Z case study is to consider the relative cost saving of different risk finance strategies to cover the losses caused by tropical cyclones. The contingent liability being considered for Country Z is the required public expenditure to finance reconstruction of public capital infrastructure destroyed or damaged due to tropical cyclones.
- Since the primary focus of the analysis is in assessing the relative costs and benefits of the finance strategies, this case study assumes that government finance strategies are exhausted at the 1 in 50 year return period. Beyond this point, it is assumed that donor support would be provided, and rather than model this cost that would be the same in all strategies, the contingent liability losses are capped at the 1 in 50 year return period.
- This chapter is structured with results presented in the main body for four different strategies. First the report sets out the risk finance strategies under consideration (Section 1) and the base assumptions and approach used to assess the strategies (Section 2). Following that, the results in the base case scenario (Section 3) and sensitivity scenario (Section 4) are presented. Supporting diagrams and comments are included for the underlying contingent liability (Annex Z1), the base case assumptions (Annex Z2) and the sensitivity analysis (Annexes Z3 and Z4).

1. Country Z – Risk Finance Strategies

- The analysis for Country Z looks at the cost of alternative finance strategies.
- All of the finance strategies considered are assumed to sit on top of a reserve fund that is established to meet approximately the 1 in 6 year contingent liability (a loss equal to roughly 0.2 percent of GDP or US$25m). All strategies also assume that if the additional measure being considered is exhausted then post-disaster debt will be issued by Country Z.
- The alternative strategies and finance instruments considered for Country Z analysis are summarized in Table 2.1 below.

Table Z1.1 – Strategies Considered

Layer	Strategy A	Strategy B	Strategy C	Strategy D
First	Reserve fund	Reserve fund	Reserve fund	Reserve fund
↓	Post-disaster debt	Insurance	Budget reallocations	Contingent credit
Last		Post-disaster debt	Post-disaster debt	Post-disaster debt

2. Country Z – Approach and Assumptions

Natural hazard assumptions

- The analysis is based on 10,000 simulated years of losses caused by tropical cyclone events across the entire country. These simulated losses were extrapolated from an extract of return period losses from a third-party catastrophe modelling report. Annex Z1 includes further detail on the underlying distribution of losses.
- Since our analysis is only interested in public capital losses, it is assumed that 30 percent of the losses are public capital losses, in line with the proportion of exposure assumed to be public capital in the underlying catastrophe model.
- Public capital losses have been capped at the 1 in 50 year return period (approximately US$300m or 2.5 percent of GDP). Losses beyond this magnitude are assumed to be financed by donor support in any finance strategy – the cost of this donor support would be consistent for all strategies and is excluded from this analysis.

Economic and risk transfer assumptions

2.1. Key assumptions, base parameters, and sensitivity analysis performed are summarized in Table Z2.1:

2.2. Further details on the sources of the base assumptions, as well as other parameters not material for sensitivity analysis, are outlined in Annex Z2.

Table Z2.1 – Assumptions Summary, Base Parameters and Sensitivity Analysis

Assumption	Base Parameter	Sensitivity Analysis	Reference of Where Results Are Presented
Reserve fund maximum	US$25m	Double the maximum to US$50m	Figure AZ4.3 – Figure AZ4.4
Spread between interest rate & investment return	3% (interest rate = 6.75%; investment return = 3.75%)	Increase in the spread from 3% to 5% Decrease in the spread from 3% to 1%	Figure AZ3.2
Contingent credit maximum	US$30m	Double the maximum to US$60m	Figure AZ4.3 – Figure AZ4.4
Contingent credit arrangements	2.5% interest on used funds, 0.5% arrangement fee	Consider reduced interest (1%)	Figure AZ3.4
Insurance maximum limit	1 in 30 year loss	1 in 15 year loss	Figure AZ4.1 – Figure AZ4.2
Risk volatility loading	25% (broadly equivalent to an insurance pricing multiple of 1.85)	Decrease to 12.5% (multiple of 1.4) and increase to 45% (multiple of 2.5)	Figure AZ3.3
Amount of budget reallocation	US$100m	Double the maximum to US$200m	Figure AZ4.3 – Figure AZ4.4
Budget reallocation hurdle rate	37%	Decrease to 10% and increase to 50%	Figure AZ3.2
Post-disaster debt delay factor	18.4%, based on underlying assumptions outlined in Annex Z2	Increase to 38% (equivalent to a post-disaster borrowing rate of 8%, rather than 6.75% ex ante rate)	Figure AZ3.3
Contingent liability	Third party model of losses caused by tropical cyclone events	Not considered	

3. Country Z – Base Case Scenario Results

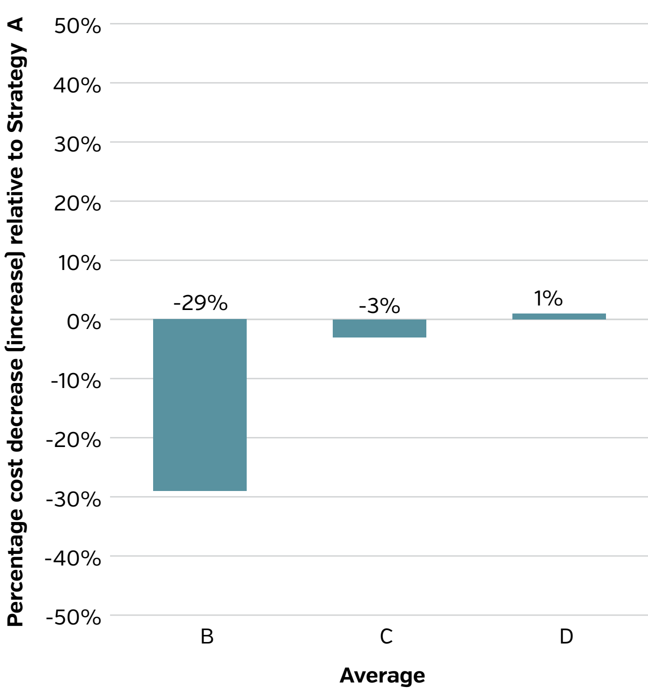
3.1. This section outlines the total costs for the four strategies considered. Costs are shown at different return periods, to highlight which strategies are cheapest at covering the average loss, loss events of a lower magnitude, and more extreme loss events. For the Country Z case study, the cost of the four strategies outlined above over the following return periods are considered:

- On average
- 1 in 10 year return period
- 1 in 30 year return period.

3.2. Figures Z3.1, Z3.2, and Z3.3 show the cost savings of Strategies B, C, and D relative to Strategy A. In other words, they show the relative cost saving or cost from having a finance instrument that sits between the reserve fund and Country Z's post-disaster debt.

3.3. Figure Z3.1 presents the relative cost savings of Strategies B, C, and D on average, under the base assumptions.

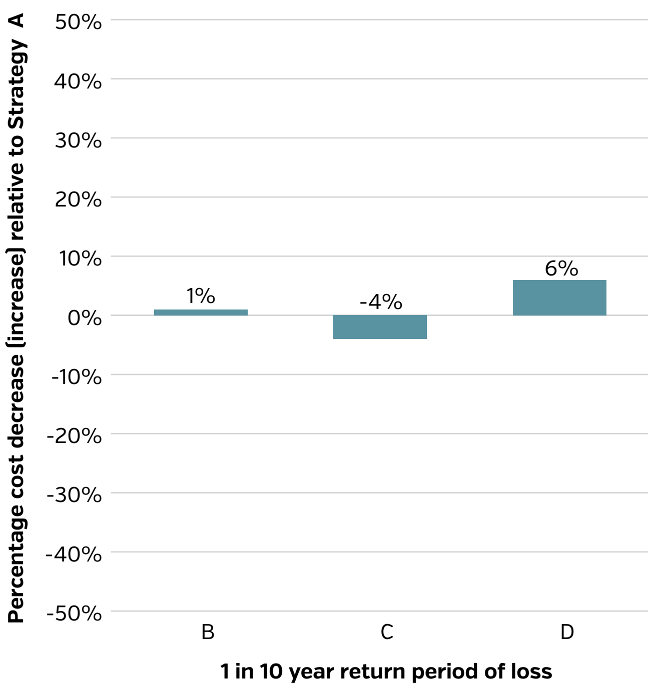
Figure Z3 .1 – Relative Cost Saving of Finance Strategies, Base Case Scenario, Average Cost



Source: Clarke, Cooney, Edwards, and Jinks (2016).

- The average cost of Strategy B (insurance) is around 30 percent higher than the average cost of Strategy A. This is because the insurance premium payable covers for higher loss scenarios.
- The average cost of Strategy C (budget reallocation) is around 3 percent higher than the average cost of Strategy A. This is because the hurdle rate is higher than the assumed cost of post-disaster debt.
- The average cost of Strategy D (contingent credit) is around 1 percent lower than the average cost of Strategy A. This is because the contingent credit interest rate is lower than the government borrowing rate.

Figure Z3 .2 – Relative Cost Saving of Finance Strategies, 1 in 10 Year Return Period Loss

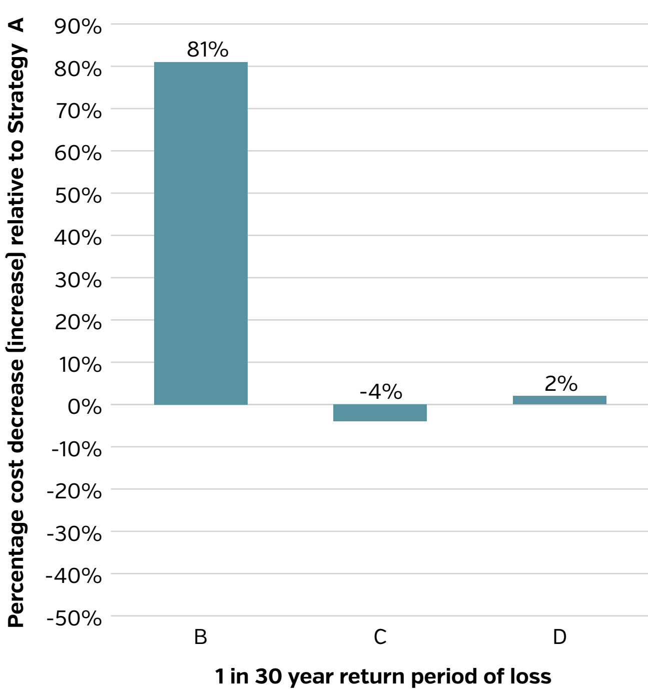


Source: Clarke, Cooney, Edwards, and Jinks (2016).

3.4. Figures Z3.2 and Z3.3 demonstrate the same analysis at the 1 in 10 and 1 in 30 return periods.

- At the 1 in 10 return period, Strategies B, C, and D do not require post-disaster debt to be issued because the finance instrument are sufficient to meet the losses.
- Strategy B starts to appear cheaper (relative to Strategy A) as the size of the premium relative to the size of the loss reduces.
- The cost of Strategy C (with budget reallocation) continues to be the higher than Strategy A because of the high hurdle rate.
- The cost of Strategy D (with contingent credit) is the cheapest because of the relatively low contingent credit interest rate.

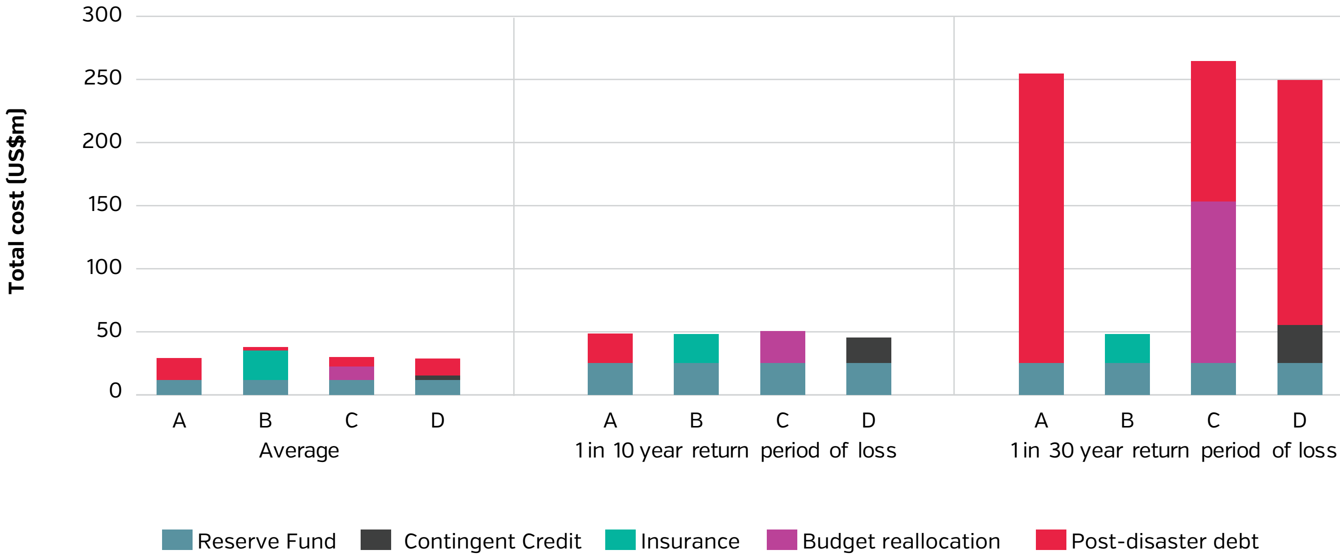
Figure Z3 .3 – Relative Cost Saving of Finance Strategies, 1 in 30 Year Return Period Loss



Source: Clarke, Cooney, Edwards, and Jinks (2016).

- For greater losses at higher return periods, Strategy B is significantly (at the 1 in 30 year, 81 percent) cheaper than other strategies because a significant proportion of the large losses are ceded to the insurer.
- Strategy C (with budget reallocation) has the highest cost because of the high hurdle rate.
- The cost of Strategy D (with contingent credit) is slightly lower than the costs of Strategies A and C because of the relatively low contingent credit interest rate.

Figure Z3.4 – Cost of Finance Strategies, Base Case Assumptions



Source: Clarke, Cooney, Edwards, and Jinks (2016).

3.5. While Figures Z3.1, Z3.2, and Z3.3 compare the relative cost saving of the strategies at different return periods, it does not allow a direct comparison of the magnitude of the costs. Figure Z3.4 shows the cost, in monetary terms of the different strategies at the different return periods.

3.6. The main conclusions from the base case scenario are:

- The costs of Strategy B (insurance) are highest at lower return periods because the insurance premium exceeds the average loss (which is roughly at the 1 in 7 year return period).
- At higher return periods, the costs of Strategy B are significantly lower than the costs of the other strategies as losses are passed onto the insurer.
- Strategy C always has the greatest cost due to the relatively higher budget reallocation costs compared to other finance instruments.
- At the return periods shown, the cost of Strategy D is lower than the cost of Strategies A and C because the assumed interest rate of contingent credit is much lower than the costs associated with budget reallocation or post-disaster debt issuance.

4. Country Z – Sensitivity Results

4.1. Country Z case study considers sensitivity analysis to:

- The economic and financial assumptions used to derive the costs of the strategies
- The maximum amount of losses covered by the different finance strategies.

Sensitivity Results: Varying the Economic and Financial Assumptions

4.2. A marginal cost analysis for each finance instrument is used to demonstrate their features and benefits over varying return periods. The marginal cost analysis in Annex Z3 demonstrates the intuitive notion that as the economic cost of a finance source increases, the attractiveness of that source decreases, namely:

- Reserves are marginally the cheapest finance instrument up to approximately the 1 in 7.6 year return period, after which post-disaster debt becomes the cheapest instrument.

4.3. The results indicated by the marginal costs analysis are dependent on the financial and other assumptions selected. If these assumptions are varied the outcomes can be materially different. Sensitivity to economic parameters for each of these finance instruments is also demonstrated in Annex Z3. The results vary intuitively as the economic parameters are adjusted and the following can be noted:

- Increasing the insurance risk volatility loading decreases the cost benefit gained from insurance.
- Increasing the delay factor makes post-disaster debt less attractive.
- Increasing the spread between the investment and borrowing rates increases the marginal cost of the reserves as it increases the cost of holding reserve funds which may not be called on.
- Similarly, increasing the interest charged on contingent credit reduces the cost benefit of the contingent credit.
- Decreasing the budget reallocation hurdle rate increases the cost-effectiveness of the budget reallocation layer.

Sensitivity Results: Varying Maximum Funding by Finance Instrument

4.4. The results shown in the base case scenario are dependent on the amount of funding assumed to be available by each financial instrument. Sensitivity to the size of the layers is demonstrated through examination of the total cost analysis. The results (see Annex Z4 for details) vary intuitively as the amounts available from each financial instrument are adjusted, with the following key results:

- Increasing the amount of financing available from reserve and budget instruments reduces the cost at higher return periods because fewer finance costs are met by budget reallocation and post-disaster debt, which are typically more expensive.
- Decreasing the exhaustion point (maximum loss covered) of insurance demonstrates that at higher return periods, post-disaster debt is now required, hence increasing the total cost.

5. Country Z – Concluding Remarks

5.1. The analysis shows that when considering tropical cyclone events, losses which are of a lower impact and occur more frequently are likely to be most cost-effectively financed by contingent credit. However, there is unlikely to be sufficient contingent credit available to provide cover for larger losses and hence post-disaster debt is likely to be required.

5.2. Post-disaster debt is assumed to have the lowest marginal cost at the higher loss events. However, strategies with insurance attaching at a lower return period had a much lower total cost – reflecting the fact that using insurance results in losses being ceded to the insurer.

5.3. The most cost-effective strategy will depend on the risk tolerance of policy makers and realistic amounts available from each financial instrument. In practice, the government may wish to combine insurance with another instrument such that only a percentage of the layer is ceded out for reinsurance, and the rest is financed through other instruments. The impact of only ceding a percentage of the layer would be similar to that of reducing the insurance exhaustion point.

Guidance Note

The purpose of this Guidance Note is to give guidance on the steps that should normally be taken to conduct an evaluation of alternative of sovereign disaster risk finance strategies. This note should be read in conjunction with the formulae and descriptions in the World Bank Policy Research Working Paper, "Evaluating Sovereign Disaster Risk Finance Strategies: A Framework," by D.J. Clarke, O. Mahul, R. Poulter, and T.-L. Teh (hereafter, the Framework Paper).

1. Define Contingent Liability

Define the expenditures (or losses) that would be financed by government and/or development partners in the aftermath of potential future natural disasters (for example, tropical cyclones, earthquakes, floods, droughts).

The underlying expenditures considered should have a clear element of uncertainty and a way to probabilistically model this uncertainty through a set of simulated expenditures. Typically expenditures are simulated over a 12 month period, to coincide with agricultural or tropical cyclone seasons, or the annual budgeting period of government. This data on simulated expenditures might come from a natural catastrophe model, from a distribution fitted to historic loss data, or from other sources. The contingent liability being considered for financing could be a truncation or a layer of the underlying expenditures (losses).

2. Define Finance Strategies and Layers

Select potential financial instruments to be considered and in which combination, such as:

- Risk transfer instruments including insurance, reinsurance, catastrophe swaps, and catastrophe bonds
- Reserves / ex-ante budget allocations
- Contingent credit
- Emergency ex-post budget reallocations
- Ex-post direct credit (borrowing/ post-disaster debt)

Define which instruments will act to finance the contingent liability, in which order, and to what extent.

- The minimum and maximum point at which each instrument will finance the liability, as well as the total maximum funding available from each instrument should be defined.
- The source of the financing may be from national or subnational government, or from development partners. Any application of the framework should include a suitable caveat about how much reliance can be placed on the results by a government if the funding sources is unspecified.
- One of the instruments will require an assumption that it is unlimited so that the entire contingent liability can be fully financed. This is usually assumed to be post-disaster debt.

Each combination of one or more instruments that in aggregate can precisely finance the entire contingent liability is then considered a strategy. Typically comparing three to four overall strategies yields the most insight without introducing too many considerations or assumptions.

3. Set Base Assumptions

Assumptions about the economic and commercial environment

- Interest rates (that is, borrowing rates) should normally be taken to be consistent with market-implied interest rates for sovereign debt, consistent with the currency used for analysis (that is, for analysis in US$, Eurobond debt rates issued in US$ should be used).

- The discount rate used to discount costs incurred in the future into present day terms should normally be chosen to equal the marginal interest rate on pre-disaster sovereign debt.
- The investment return on undisbursed contingency funds or budgets should normally be chosen to be consistent with the asset classes the funds or budget lines are invested in. This is expected to be lower than the market-implied interest rate.
- The hurdle rate of return for projects that would have funding cut in the case of budget reallocations can be taken from any government rules on the social rate of return required on projects, or other economic studies of the internal rate of return of public expenditure. The hurdle rate may vary for different tranches of reallocations (that is, the first few US$m of reallocations might be subject to a lower hurdle rate than the next few US$m). For simplicity, it is usually best to set one hurdle rate and assume a limit on the maximum amount of budget reallocation available that might be subject to this hurdle rate.
- Where possible, ex-post borrowing rates and delay factors should be taken from economic studies.
- Rules of thumb for pricing risk transfer instruments should be designed to approximate market pricing as closely as possible.

In some circumstances it may be appropriate to make different assumptions depending on the source of funds, for example, if some parts of government or some development partners are able to offer budget reallocations at lower opportunity cost than others. However, typically it may be reasonable to set assumptions that are neutral to the source of the funding – that is, such that they could apply to funding from the government or from external development partners.

4. Calculate Results under Base Assumptions

Calculate the opportunity cost for each strategy for each simulation of the contingent liability:

- Refer to the Framework Paper for formulae to calculate the opportunity cost of each financial instrument depending on the quantum of the layer financed by the instrument. These formulae may be adjusted where appropriate, for example, to allow for a different rule of thumb for pricing risk transfer instruments.
- Demonstrating the savings of certain alternative strategies compared to a base strategy is a helpful way to present results.
- This will typically be for 10,000 or more simulated annual expenditures; however, 5,000 simulations is likely sufficient to consider lower return periods.

Present the resulting opportunity cost results at return periods that are relevant for or requested by the stakeholders of the analysis.

  - For example, for catastrophic natural disasters (tropical cyclone, earthquake), at the mean, 1 in 10 and 1 in 50 year results may be relevant.
  - For disasters such as flood or drought, at least the mean, 1 in 5 and 1 in 30 year results may be relevant.

5. Consider Relevant Sensitivities and Re-Calculate Results

Sensitivities involve considering alternative parameters for the layers, economic assumptions, or risk transfer assumptions.

- Sensitivities may be driven by the uncertainty of certain parameters (for example, discount rate) or by the political landscape of the country (such as, available emergency budget reallocation may be very limited, but it is insightful to consider what significantly increasing this might do to the risk finance strategies).
- Economic assumption sensitivities can be succinctly presented through the use of marginal opportunity cost charts.

Re-calculate the results as in (4) and consider how the assumptions changes impact which strategies are the most cost-effective at various return periods.

6. Conclude on Risk Finance Implications

A combination of base result and sensitivity analysis should demonstrate:

- Which strategies tend to have the lowest opportunity costs on average and at various return periods
- Which assumptions and parameters have the greatest impact on the results.

Reporting should summarise the conclusions, and also consider any limitations of the analysis or any additional implicit assumptions that have been made.

The most cost-effective strategy will depend on the assumptions, the risk tolerance of policy makers, and potentially other considerations. Any conclusions and results also need to be interpreted in the context of the objectives of the stakeholders of the analysis.

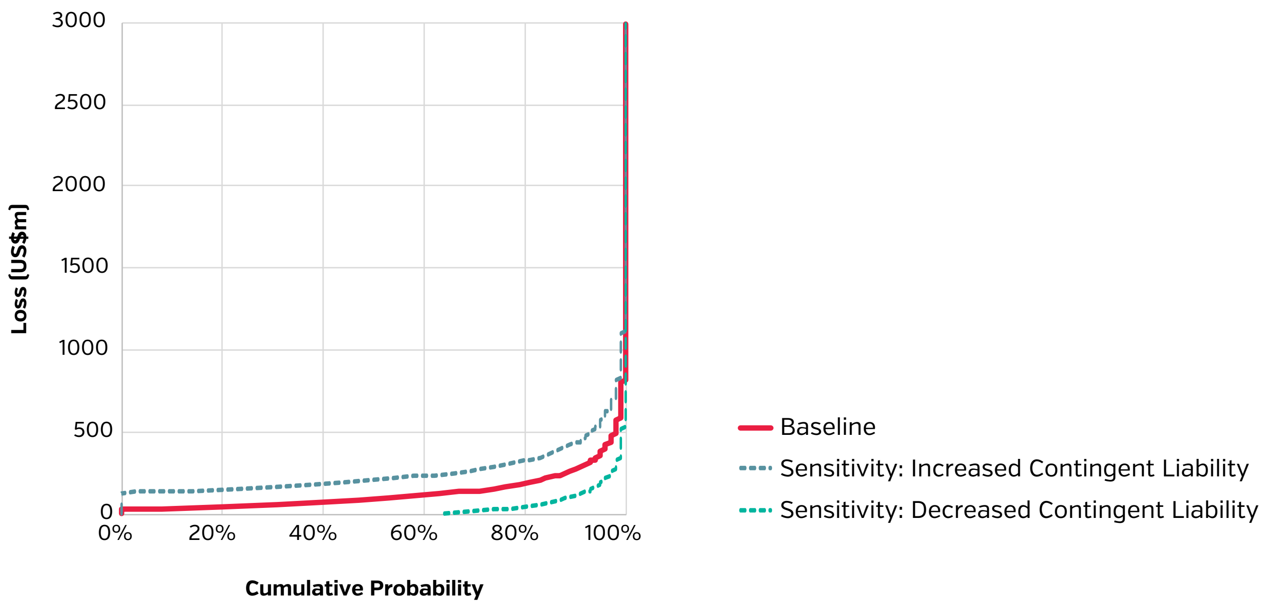
Country V Annexes

Annex V1 – Contingent Liability

Figure AV1.1 demonstrates the cumulative distribution function of the costs associated with supporting food insecure households in districts across the country affected by drought. This cumulative distribution function of the contingent liability demonstrates a long tail of extreme potential losses.

The sensitivity of the assumed loss distribution is considered further in Annex V4 and the alternative loss distributions considered are also shown in Figure V1.1.

Figure AV1.1 – Cumulative Distribution Function of the Poverty Cost Due to Drought



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Annex V2 – Assumptions

Reserve fund assumptions (all strategies)

Under all strategies, initial losses are retained through a reserve fund. The base case assumes that the reserve fund is assumed to be equal to US$50m, which is equal to a 1 in 1.3 year event.

The cost of reserve funds reflects the assumption that Country V has to borrow to fund the reserves and has to pay interest on the amount borrowed. While this is offset by the investment returns achieved on the reserves, the investment returns are typically assumed to be lower than the borrowing rate. The economic assumptions required for calculating the cost of reserve fund are therefore:

- Discount rate used to discount costs incurred in the future into present day terms
- Interest rate on amounts that are borrowed to fund reserve fund
- Investment return earned on reserve funds not used to finance costs.

The interest rate charged on amounts borrowed to fund the reserve fund is assumed to be 6.625 percent.

The reserve fund is assumed to be invested in low risk assets, hence it is assumed that the investment return earned is equal to the borrowing rate, minus a spread of 3 percent.

For simplicity, it is assumed that the discount rate is the same as the borrowing rate – varying this assumption does not have a material effect on any conclusions drawn in this case study.

Post-disaster debt assumptions (all strategies)

Delay factor for post-disaster debt response: This is the impact on benefit costs due to a delay in providing response (for example, due to reliance on slow finance instruments such as post-disaster debt). Currently this is assumed to be equivalent to a factor of 3, such that US$1 early (immediate financing of drought losses) is equivalent to US$3 late (post-disaster debt-financed), based on a review of literature on this topic for this country.

Insurance assumptions (Strategy B)

Strategy B assumes that insurance will start to payout once the reserve fund has been exhausted. The base case insurance contract structure is defined as follows:

- **Insurance Coverage:** The attachment point is 1 in 1.3 year losses when the reserve fund is exhausted. The insurance layer is assumed to cover losses up to the 1 in 30 year event (equivalent to US$433.4m).
- **Insurance Premium:** The annual premium payable is US$105m for drought cover. The assumed premium was set using a pricing multiple of 1.35, which is representative of the drought peril insured at the time of writing this paper. Fees and expenses associated with insurance mechanisms are assumed to be included within the premium.

Budget reallocation assumptions (Strategy C)

Strategy C assumes that once the reserve fund has been exhausted, Country V will reallocate existing budgets to fund the finance costs. The base case assumes that Country V is able to reallocate budgets equal to US$100m, such that, together with the reserve fund, the maximum budget available to finance costs is US$150m (equivalent to a 1 in 3.6 year event).

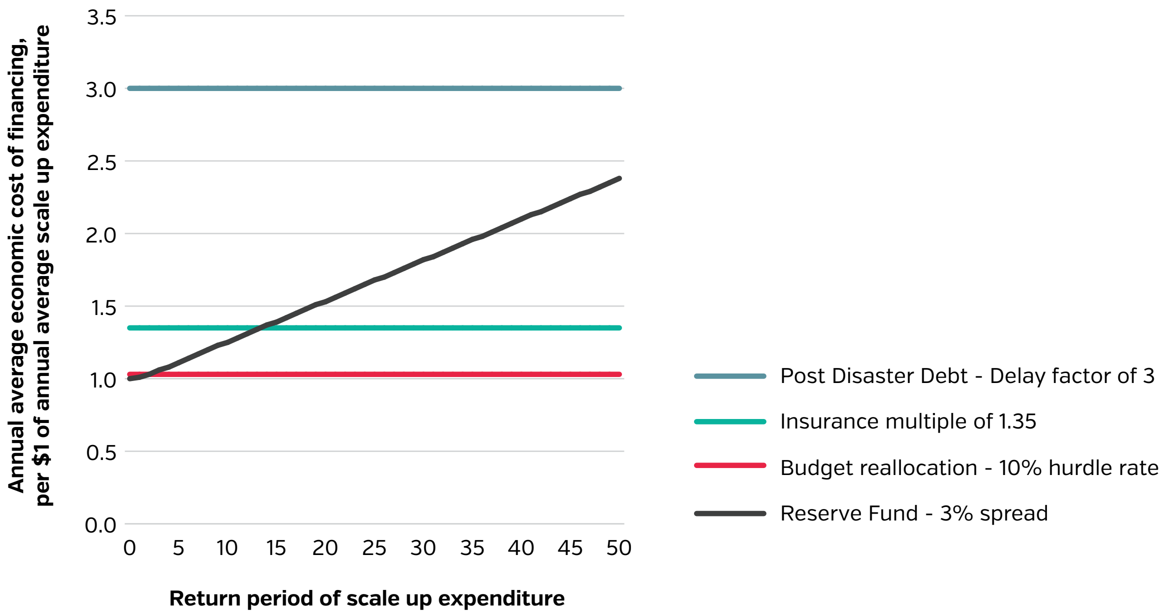
It is assumed that the cost of reallocating budgets is a hurdle rate of 10 percent.

Annex V3 – Sensitivity Analysis: Economic and Financial Assumptions

Marginal cost – base case scenario

Figure AV3.1 compares the marginal cost (as a multiple of expected loss in layer) for the various finance sources under the base case assumptions. The marginal cost represents the additional cost of each risk finance instrument per unit of annual average loss in layer, for a specific return period.

Figure AV3.1 – Marginal Cost as a Multiple of Loss, Base Case Assumptions



Source: Clarke, Cooney, Edwards, and Jinks (2016).

- The reserve fund has a marginal cost increasing in the return period due to the difference between the cost of borrowing funds (the interest rate) and the investment return earned on unspent reserves, which is lower. At losses at higher return periods, the reserve fund is less likely to be called on and therefore more likely to incur a cost of holding funds.
- Post-disaster debt has a cost of exactly 3 times the loss at all return periods by definition of the delay factor of 3. It is assumed that US$1 of aid provided early costs US$3 when the response is provided late.
- Insurance has a cost of 1.35, reflecting the constant assumed 1.35 insurance pricing multiple.
- Budget reallocation has a constant marginal cost of 1.03 under the base case scenario, representing the spread between the hurdle rate (10 percent) and the discount rate (6.625 percent).

The marginal cost does not reflect the limitations and budgetary constraints of various finance sources – most notably funds available through some instruments are cost-effective but very limited. The graph implies that theoretically, budget reallocation is most cost-effective for high finance cost return periods. However, this ignores the fact that there might be a limit on the extent to which government budgets can be reallocated.

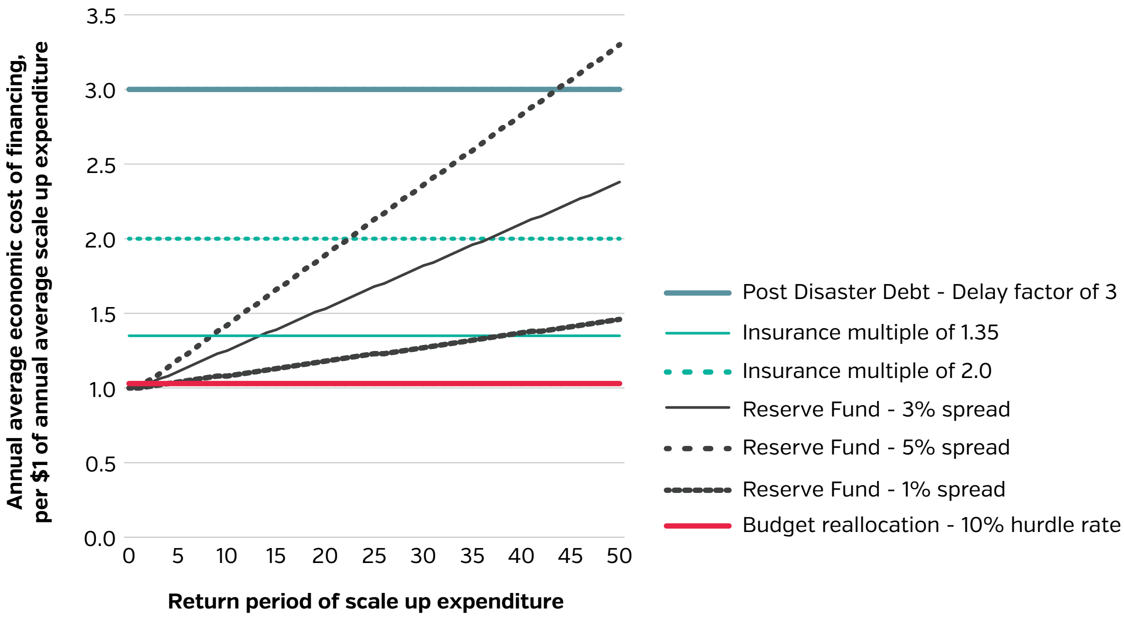
Where the different lines of marginal cost intersect is where one finance strategy becomes marginally more cost-effective than another:

- Reserve funds are the cheapest finance instrument up the 1 in 2.1 year return period.
- For losses greater than the 1 in 2.1 year loss, budget reallocation is always marginally the cheapest finance instrument.
- Reserve funds remain the second cheapest between the 1 in 2.1 year and the 1 in 13.4 year loss, after that insurance is the second cheapest.

Marginal cost - sensitivities

Figures AV3.2 and AV3.3 consider the impact on the marginal cost of adjusting the following economic and financial assumptions:

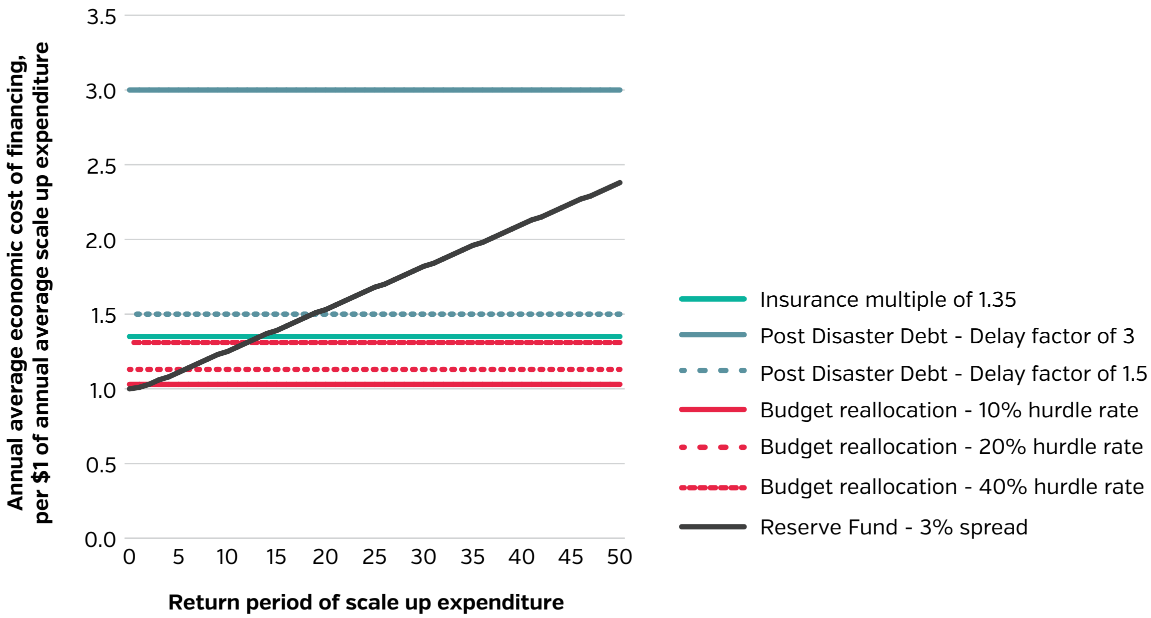
Figure AV3.2 – Marginal Cost as a Multiple of Loss, Sensitivity to the Spread on the Reserve Fund and Insurance Pricing Multiple



Source: Clarke, Cooney, Edwards, and Jinks (2016).

- Increasing the spread between the interest rate and investment return of the reserve fund increases the slope of the marginal cost line, such that the reserve fund becomes less cost-effective.
- Similarly, increasing the insurance pricing multiple increases the point at which insurance becomes marginally the least cost-effective strategy compared to reserve fund.

Figure AV3.3 – Marginal Cost as a Multiple of Loss – Sensitivity to the Post-Disaster Debt Delay Factor and the Budget Reallocation Hurdle Rate



Source: Clarke, Cooney, Edwards, and Jinks (2016).

- Reducing the post-disaster finance delay factor shifts down the horizontal line showing the post-disaster finance cost, such that it is significantly cheaper.
- Increasing the budget reallocation hurdle rate reduces the cost-effectiveness of budget reallocation and increases the period over which contingency funds are the most cost-effective strategy.

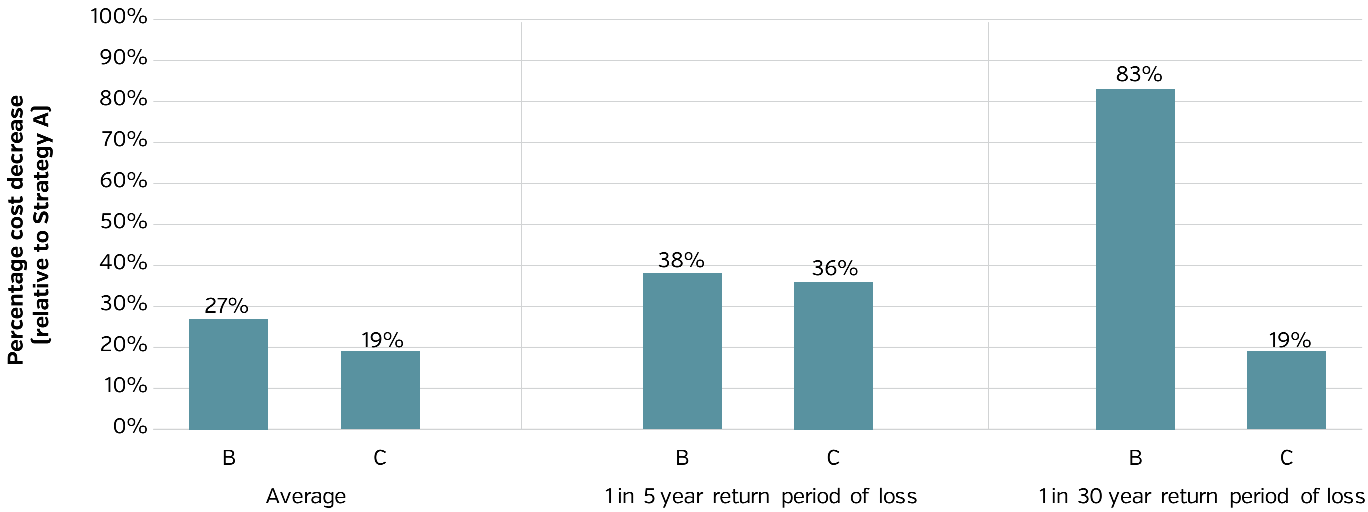
Annex V4 – Sensitivity Analysis: Varying Maximum Funding by Finance Instrument

Increased reserve fund coverage

Figures AV4.1 and AV4.2 show the cost of the three strategies over different return periods, assuming that the reserve fund is increased to US$132.1m (the average loss). For the alternative finance strategies considered:

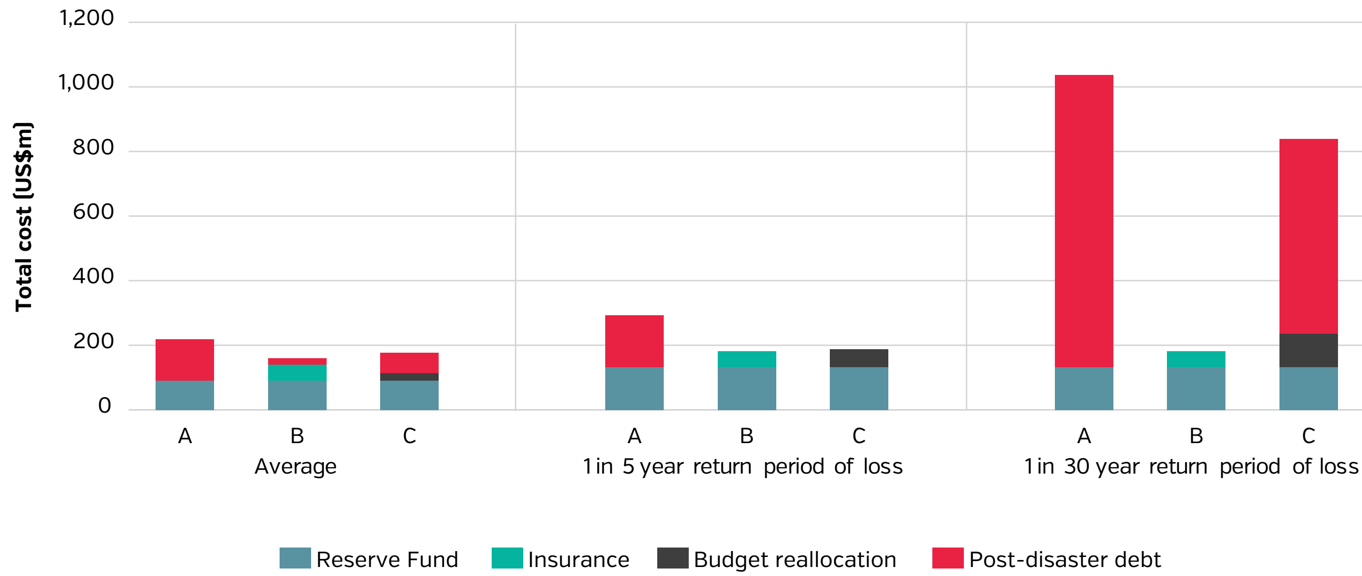
- For Strategy B, it is assumed that insurance still attaches after the reserve fund and is assumed to cover losses up to the 1 in 30 year event.
- For Strategy C, it is assumed that the government is still able to reallocate budgets equal to US$100m, such that, together with the reserve fund, the maximum budget available to finance losses is US$232.1m (equivalent to a 1 in 7.4 year event).

Figure AV4.1 – Relative Cost Saving of Strategies under Increased Reserve Fund



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Figure AV4.2 – Total Cost of Increased Reserve Fund



Source: Clarke, Cooney, Edwards, and Jinks (2016).

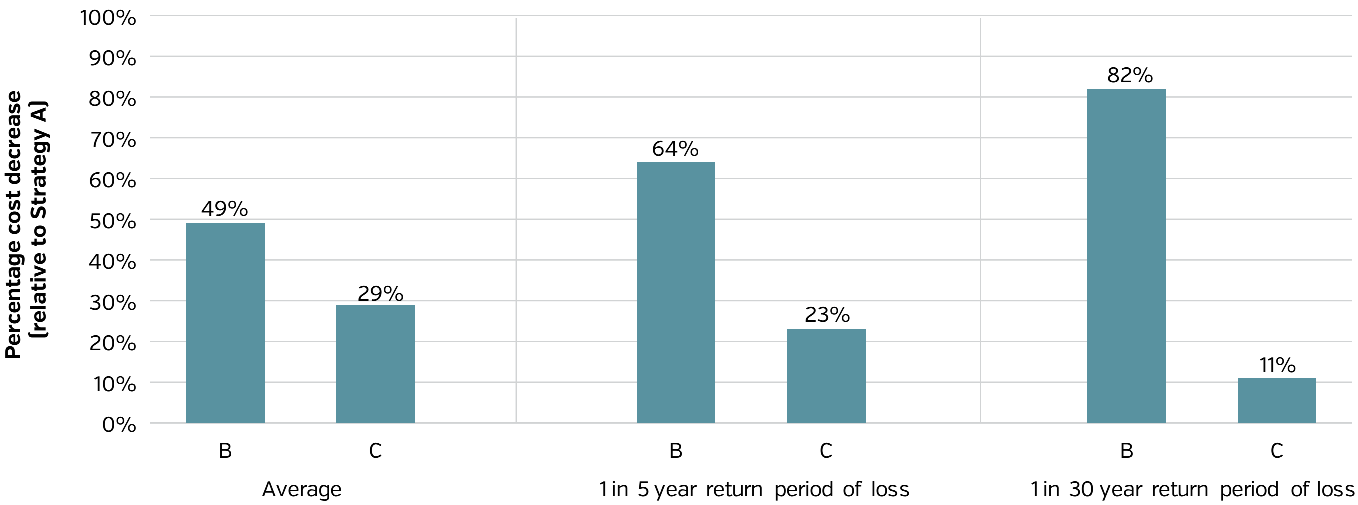
- Increasing the reserve fund decreases the average costs for all three strategies as there are more losses met from the reserve fund, which is the most cost-effective strategy.
- Strategy B is still the cheapest, both on average and at the return periods considered. Increasing the reserve fund decreases the cost savings of Strategy B relative to Strategy A as there are additional losses covered by the reserve fund in both strategies; hence the costs under both strategies are closer.
- Strategy C is still cheaper than Strategy A, but the relative savings at the higher return periods are increased. This is because there is the same absolute cost saving (in US$ terms) between Strategies A and C.

Increased underlying contingent liability

Figures AV4.3 and AV4.4 show the cost of the three strategies over different return periods, assuming that contingent losses are 25 percent higher. For the alternative finance strategies considered:

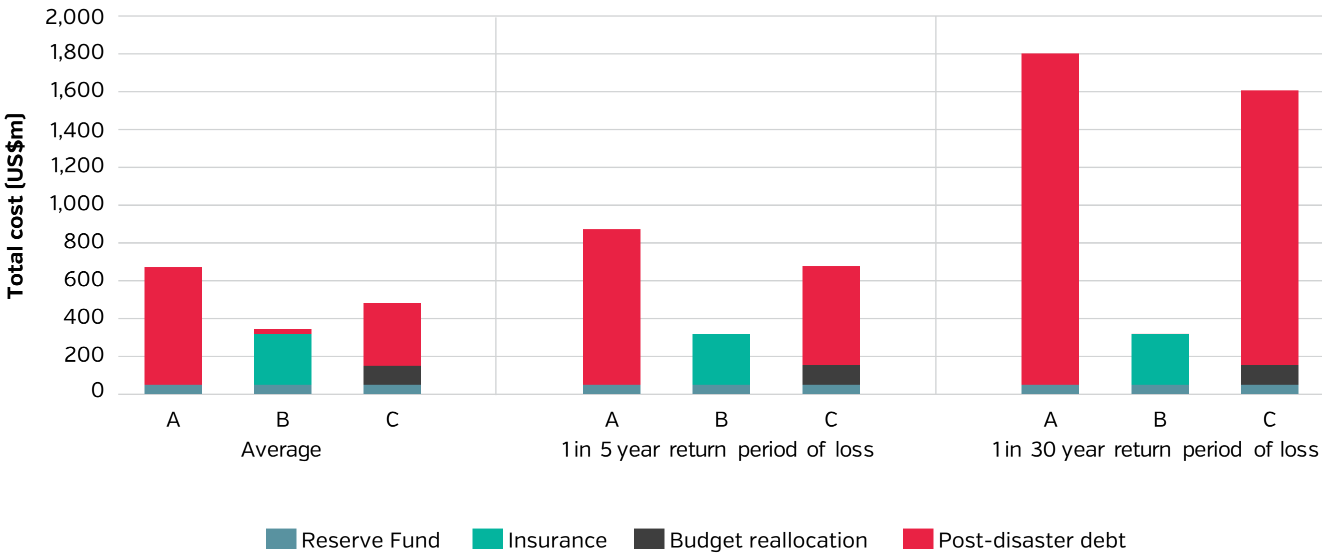
- In all strategies it is assumed that the level of reserve fund is unchanged at US$50m (note that this is exhausted in all simulations as the minimum loss is US$128m).
- Strategy B assumes that insurance still attaches after the reserve fund and is assumed to cover finance costs up to the higher 1 in 30 year event (which is now US$634m).
- Strategy C assumes that the government is still able to reallocate budgets equal to US$100m, such that, together with the reserve fund, the maximum budget available to finance costs is US$150m (equivalent to a 1 in 1.2 year event).

Figure AV4 .3 – Relative Cost Saving of Strategies under Increased Underlying Contingent Liability



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Figure AV4.4 – Total Cost of Increased Underlying Contingent Liability



Source: Clarke, Cooney, Edwards, and Jinks (2016).

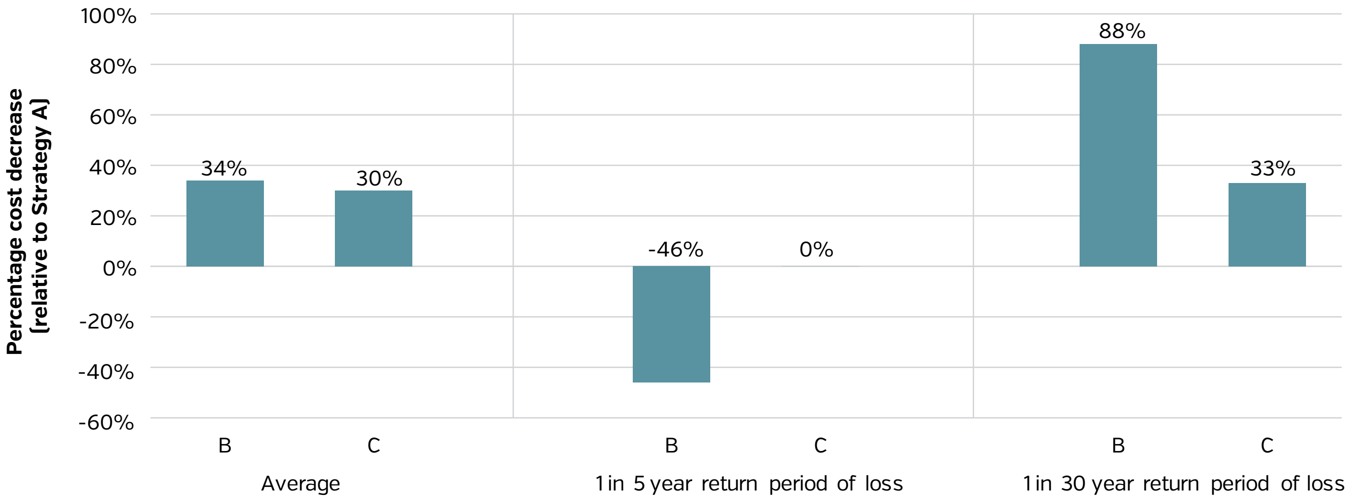
- Increasing the contingent liabilities increases the average costs for all strategies and the costs at all return periods considered.
- The cost savings of Strategy C relative to Strategy A is reduced, particularly at higher return periods because the size of the layers is unchanged and hence more losses are covered by post-disaster debt.

Decreased underlying contingent liability

Figures AV4.5 and AV4.6 show the cost of the three strategies over different return periods, assuming that contingent losses are 25 percent lower. For the alternative finance strategies considered:

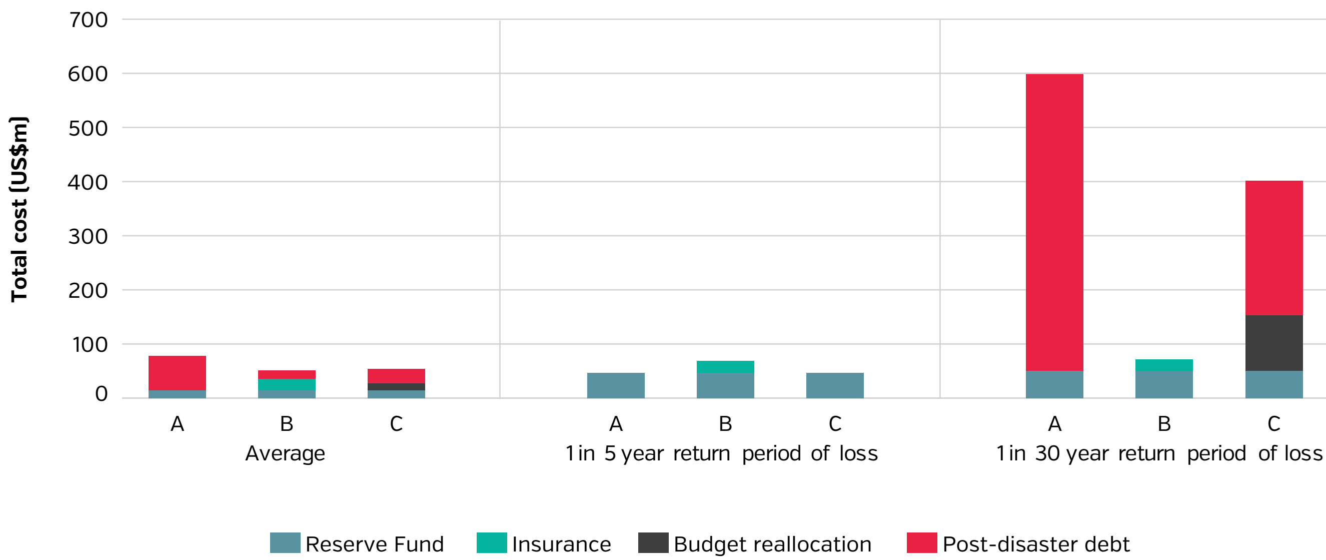
- In all strategies it is assumed that the size of the reserve fund is unchanged at US$50m (equivalent to a 1 in 5.2 year event).
- Strategy B assumes that insurance still attaches after the reserve fund and is assumed to cover finance costs up to the lower 1 in 30 year event (which is now US$233m).
- Strategy C assumes that the government is still able to reallocate budgets equal to US$100m, such that, together with the reserve fund, the maximum budget available to finance costs is US$150m (equivalent to a 1 in 14.5 year event).

Figure AV4 .5 – Relative Cost Saving of Strategies under Decreased Underlying Contingent Liability



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Figure AV4.6 – Total Cost of Decreased Underlying Contingent Liability



Source: Clarke, Cooney, Edwards, and Jinks (2016).

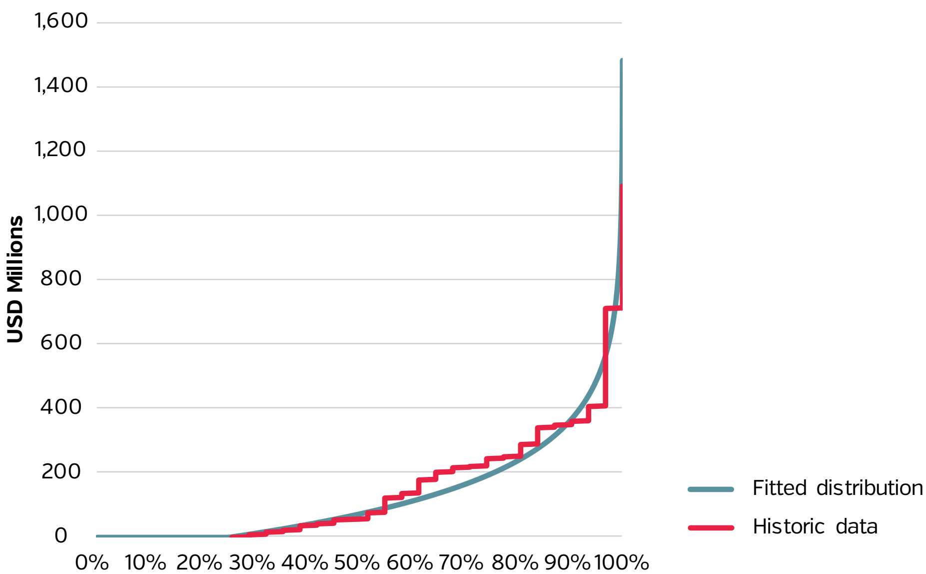
- Decreasing the contingent liabilities decreases the average costs for all strategies at all return periods considered.
- Strategy B is still the most cost-effective strategy on average and at higher return periods.
- At lower return periods, Strategy B is more expensive than Strategy A. This is because at these low return periods, losses are met from the reserve fund. However the insurance premium is still payable.
- The cost savings of Strategy C relative to Strategy A is reduced at lower return periods and on average. This is because at these low return periods, losses are met from the reserve fund and hence the costs are identical under Strategies A and C. At higher return periods, the cost savings of Strategy C is more pronounced as a higher share of the loss is met from budget reallocation.

Country W Annexes

Annex W1 – Contingent Liability

Figure AW1.1 demonstrates the cumulative distribution function of the public capital losses relating to the cost of poverty due to flood. This cumulative distribution function of the contingent liability demonstrates a long tail of extreme potential losses. Both historical data and the fitted distribution assume a US$100 per person cost.

Figure AW1.1 – Cumulative Distribution Function of the Poverty Cost Due to Flood



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Annex W2 – Assumptions

Reserve fund assumptions (all strategies)

Under all strategies, initial intial losses are retained through a reserve fund. The base case assumes that the reserve fund is assumed to be equal to US$100m, which is equal to a 1 in 2.3 year event.

The cost of reserve funds reflects the assumption that Country W has to borrow to fund the reserves and has to pay interest on the amount borrowed. While this is offset by the investment returns achieved on the reserves, the investment returns are typically assumed to be lower than the borrowing rate. The economic assumptions required for calculating the cost of reserve fund are therefore:

- Discount rate used to discount costs incurred in the future into present day terms
- Interest rate on amounts that are borrowed to fund reserves

- Investment return earned on reserve not used to fund the losses.

The interest rate charged on amounts borrowed to fund the reserves is assumed to be 13 percent.

The fund is assumed to be invested in low risks assets, hence it is assumed that the investment return earned is equal to the borrowing rate, minus a spread of 10 percent.

For simplicity, it is assumed that the discount rate is the same as the borrowing rate – varying this assumption does not have a material effect on any conclusions drawn in this case study.

Post-disaster debt assumptions (all strategies)

Delay factor for post-disaster debt response: This is the impact on benefit costs due to a delay in providing response (for example, due to reliance on slow finance instruments such as post-disaster debt). Currently this is assumed to be equivalent to a factor of 3, such that US$1 early (immediate financing of response costs) is equivalent to US$3 late (post-disaster debt-financed). A factor of 3 is assumed in line with recent World Bank research.

Insurance assumptions (Strategy B)

Strategy B assumes that insurance will start to pay out once the reserve fund has been exhausted. The base case insurance contract structure is defined as follows:

- Insurance Coverage: The attachment point is the 1 in 2.3 year losses when the reserve fund is exhausted. The insurance layer is assumed to cover losses up to the 1 in 30 year event.
- Insurance Premium: The annual premium payable is US$101.7m for flood cover. The assumed premium was set using a pricing multiple of 1.5, which is representative of the flood perils insured at the time of writing this paper. Fees and expenses associated with insurance mechanisms are assumed to be included within the premium.

Contingent credit assumptions (Strategy C)

Strategy C assumes that Country W has contingent credit arrangements to provide immediate liquidity in the aftermath of a flood event.

It is assumed that Country W can secure contingent credit of up to a maximum of US$100m, set equal to the reserve fund maximum for easier comparison.

To derive the opportunity cost of contingent credit, it is assumed that Country W would otherwise have to borrow the amount of the line of contingent credit from the commercial market (at the government's ex-ante borrowing rate) in order to finance the same portfolio of expenditures.

As a result, the opportunity cost of contingent credit depends not only on the assumed contingent credit interest rate but also the spread between the interest rate on amounts borrowed and the contingent credit interest rate.

The economic assumptions required for calculating the cost of contingent credit are therefore:

- Discount rate used to discount costs incurred in the future into present day terms
- Interest rate on amounts that are borrowed (the ex-ante borrowing rate)
- The interest rate charged on contingent credit.

Contingent credit interest rates, such as catastrophe risk deferred drawdown options, are set based on a spread over LIBOR. Based on current US$ LIBOR rates and IBRD lending rates, a contingent credit interest rate of 2.5 percent is assumed.

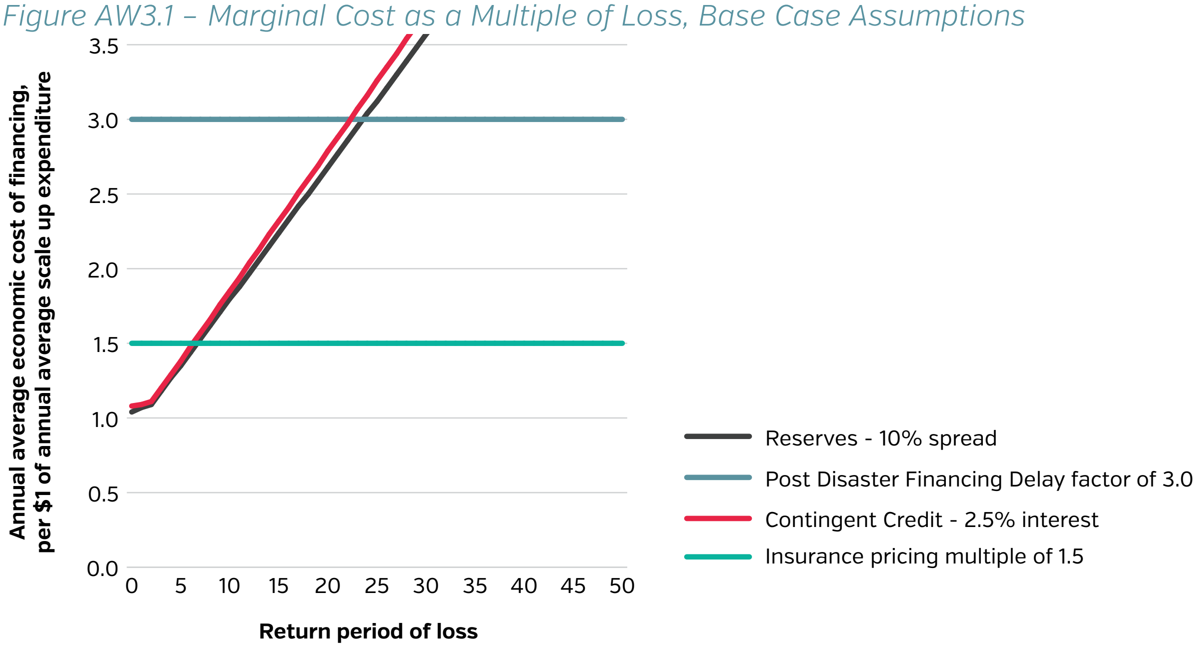
In addition to the contingent credit interest rate, contingent credit arrangements such as catastrophe risk deferred drawdown options charge fees for establishing these lines of credit. For simplicity, it is assumed that there is a single front-end fee of 0.5 percent of the maximum loan amount.

Annex W3 – Sensitivity Analysis: Economic and Financial Assumptions

Marginal cost – base case scenario

Figure AW3.1 compares the marginal cost (as a multiple of expected loss in layer) for the various finance sources under the base case assumptions. The marginal cost represents the additional cost of each risk finance instrument per unit of annual average loss in layer, for a specific return period.

Figure AW3.1 – Marginal Cost as a Multiple of Loss, Base Case Assumptions



Source: Clarke, Cooney, Edwards, and Jinks (2016).

- The reserve fund has an increasing marginal cost due to the difference between the cost of borrowing funds (the interest rate) and the investment return earned on funds held in reserves, which is lower. At higher return periods, the reserve fund is less likely to be called on and therefore more likely to incur a cost of holding funds.
- Contingent credit similarly has an increasing marginal cost due to the difference between the cost of borrowing funds (interest/discount rate) and the investment return earned on the amount of contingent credit unused, which is lower. This spread (10.5 percent being the difference between 13.0 percent and 2.5 percent) is greater than for the reserve fund and so the marginal cost increases more sharply.

- Post-disaster debt has a cost of exactly 3 times the loss at all return periods by definition of the delay factor of 3. It is assumed that US$1 of aid provided early costs US$3 when the response is provided late.
- Insurance has a cost of 1.5, reflecting the constant assumed 1.5 insurance pricing multiple.

The marginal cost does not reflect the limitations and budgetary constraints of various finance sources – most notably funds available through some instruments are cost-effective but very limited. The graph implies insurance is most cost-effective at high return periods.

Where the different lines of marginal cost intersect is where one finance strategy becomes marginally more cost-effective than another:

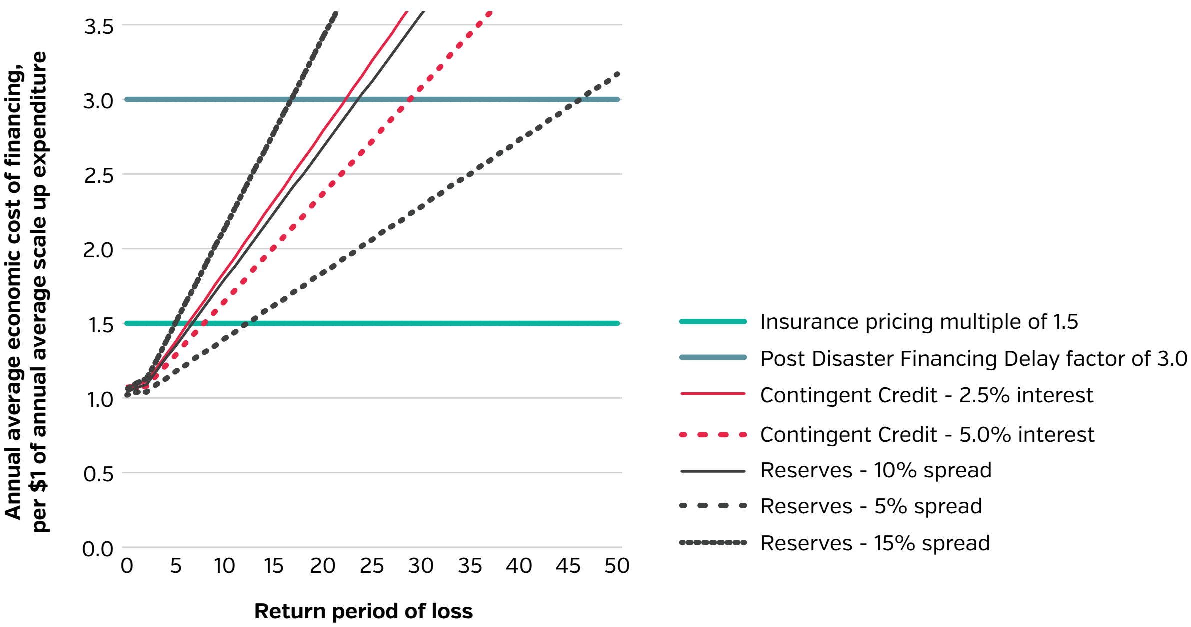
- Reserves are the cheapest finance instrument up the 1 in 7 year return period.
- For losses greater than the 1 in 7 year loss, insurance is always marginally the cheapest financing instrument.
- Reserves remain the second cheapest between the 1 in 7 year and the 1 in 24 year loss, after that post-disaster debt is the second cheapest.

Marginal cost - sensitivities

Figure AW3.2 and AW3.3 consider the impact on the marginal cost of adjusting the following economic and financial assumptions:

- Increasing (decreasing) the spread between the interest rate and investment return of the reserve increases (decreases) the slope of the marginal cost line, such that the reserve becomes less (more) cost-effective.
- Similarly, increasing the interest earned on contingent credit facilities not used to fund losses reduces the "spread" of this instrument, reducing the slope of this line and making contingent credit more cost-effective.

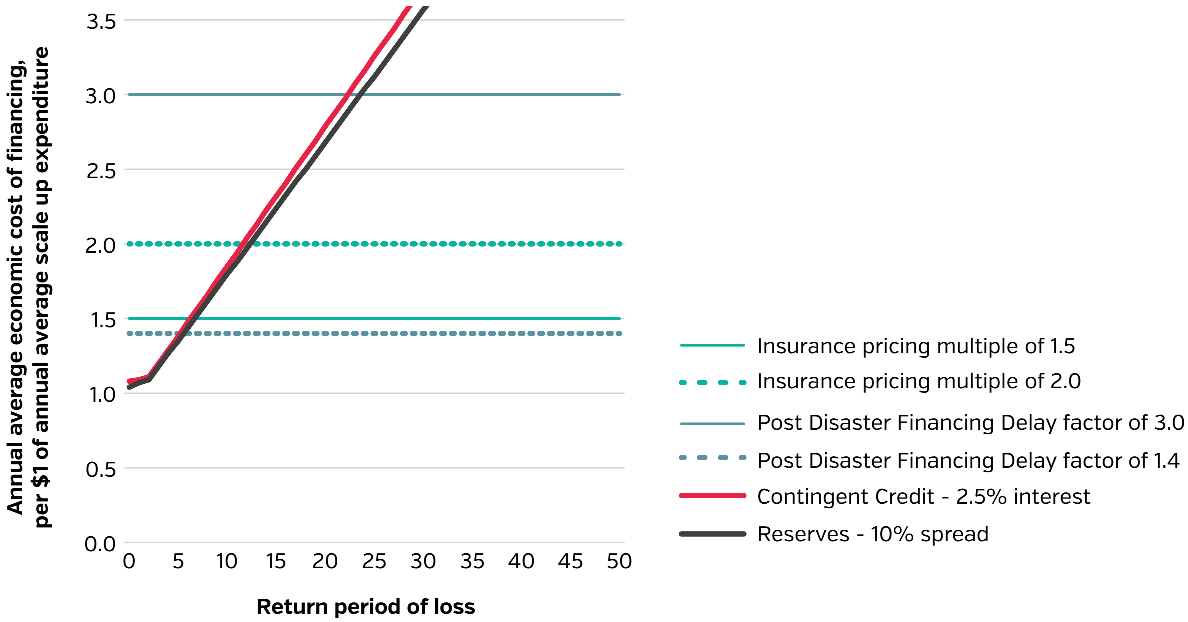
Figure AW3.2 – Marginal Cost as a Multiple of Loss, Sensitivity to the Spread on the Reserve Fund and Contingent Credit



Source: Clarke, Cooney, Edwards, and Jinks (2016).

- Increasing the insurance pricing multiple increases the point at which insurance becomes marginally the least cost-effective strategy compared to reserves and contingent credit financing.
- Decreasing the post-disaster finance delay factor shifts down the vertical line showing the post-disaster finance cost, such that it becomes a more cost-effective option – if the delay factor is lower than the insurance pricing multiple, then post-disaster debt becomes the cheapest strategy beyond a certain return period.

Figure AW3.3 – Marginal Cost as a Multiple of Loss – Sensitivity to the Post-Disaster Debt Delay Factor and the Insurance Multiple



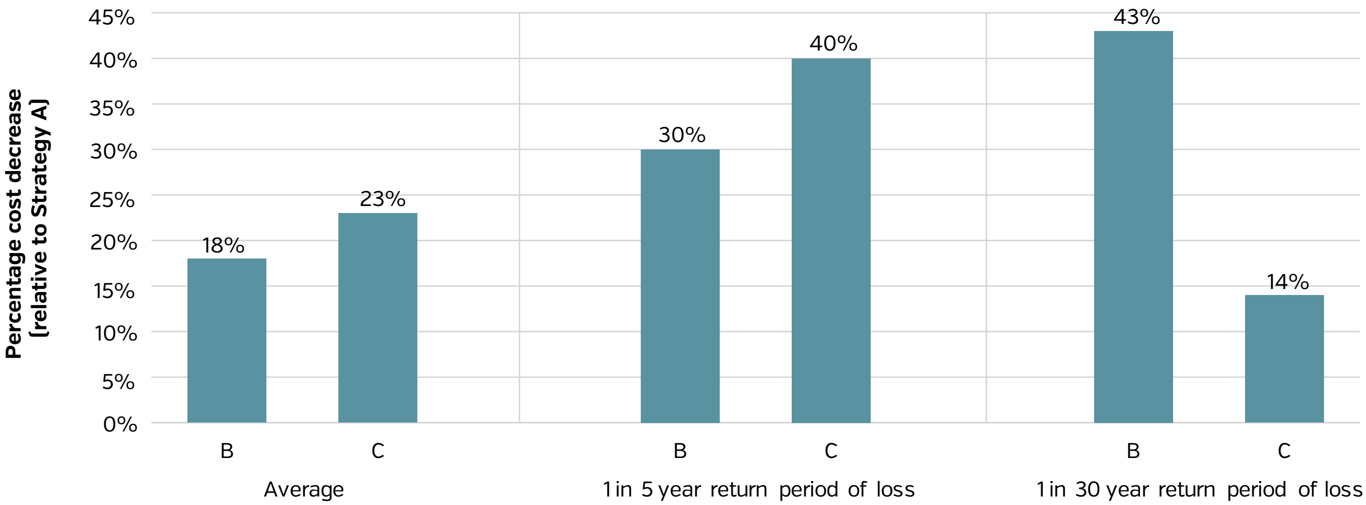
Source: Clarke, Cooney, Edwards, and Jinks (2016).

Annex W4 – Sensitivity Analysis: Varying Maximum Funding by Finance Instrument

Reduced insurance coverage

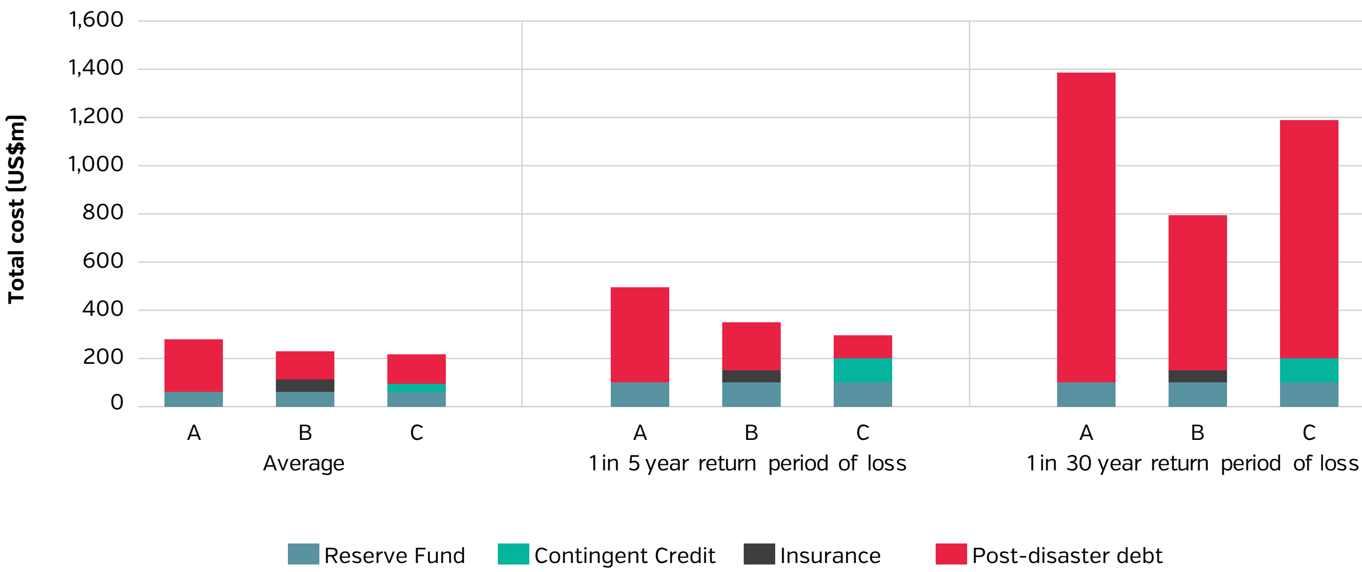
FIgures AW4.1 and AW4.2 show the cost of the three strategies over different return periods, assuming that the insurance layer covers only 50 percent of the losses between the reserve fund (1 in 2.3 year return period) and the 1 in 30 year return period loss. The remaining 50 percent is assumed to be funded by post-disaster debt.

Figure AW4 .1 – Relative Cost Saving of Reduced Insurance Layer



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Figure AW4.2 – Total Cost of Reduced Insurance Layer



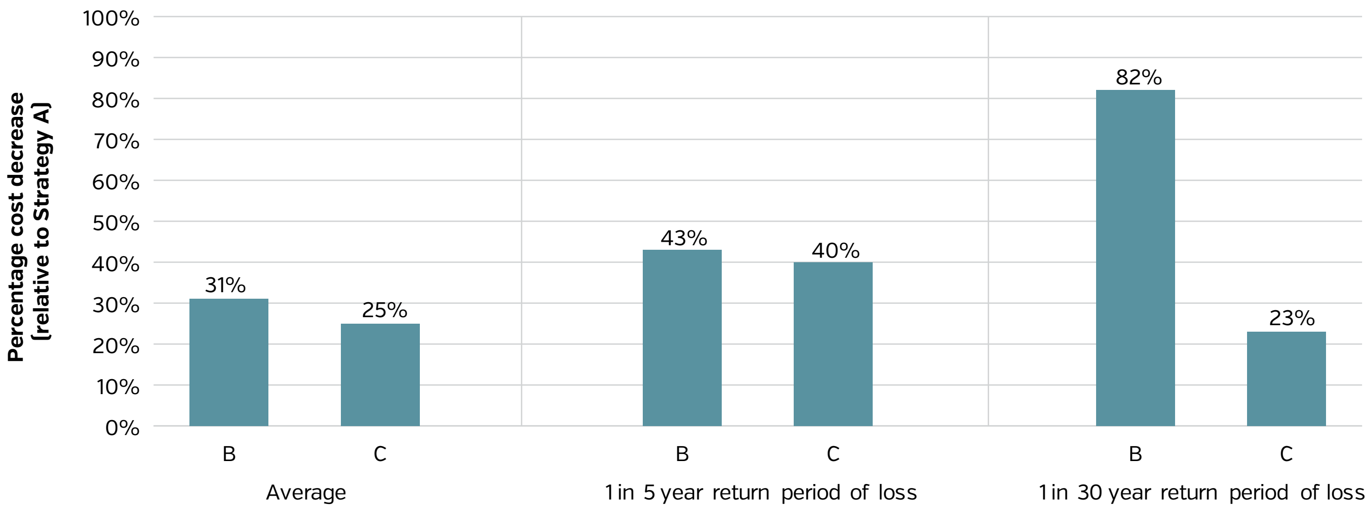
Source: Clarke, Cooney, Edwards, and Jinks (2016).

- On average and at lower return periods, the total cost of Strategy B is now higher compared to Strategy C. This is because fewer losses are covered by insurance and more losses are covered by the more expensive post-disaster debt. On average, however, Strategy B is still cheaper than Strategy A.
- Decreasing the insurance layer shows that at higher return periods, post-disaster debt is now required, hence increasing the total cost of Strategy B. While it is still cheaper than the other strategies at the 1 in 30 year return period, the saving is not as great due to the requirement for post-disaster debt.

Increase layers of non-insurance finance arrangements

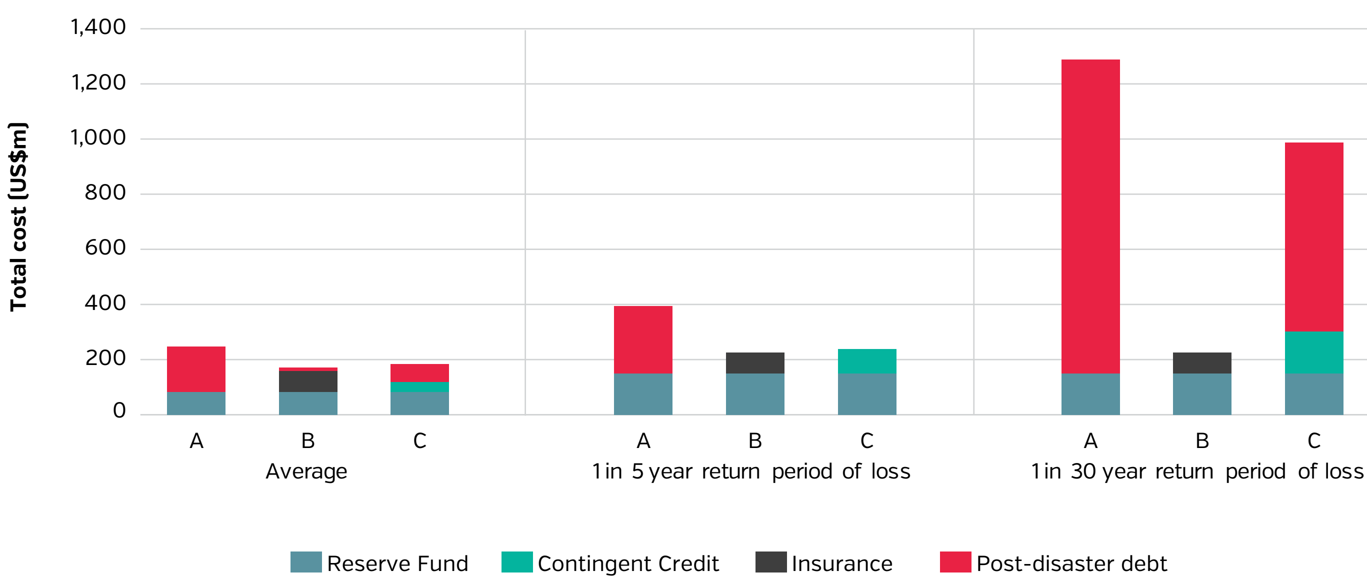
Figures AW4.3 and AW4.4 demonstrate the cost of the three strategies above over different return periods, assuming that the layers of non-insurance instruments are increased by 50 percent.

Figure AW4 .3 – Relative Cost Saving of Increasing Non-Insurance Layers



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Figure AW4.4 – Total Cost of Increasing Non-Insurance Layers



Source: Clarke, Cooney, Edwards, and Jinks (2016).

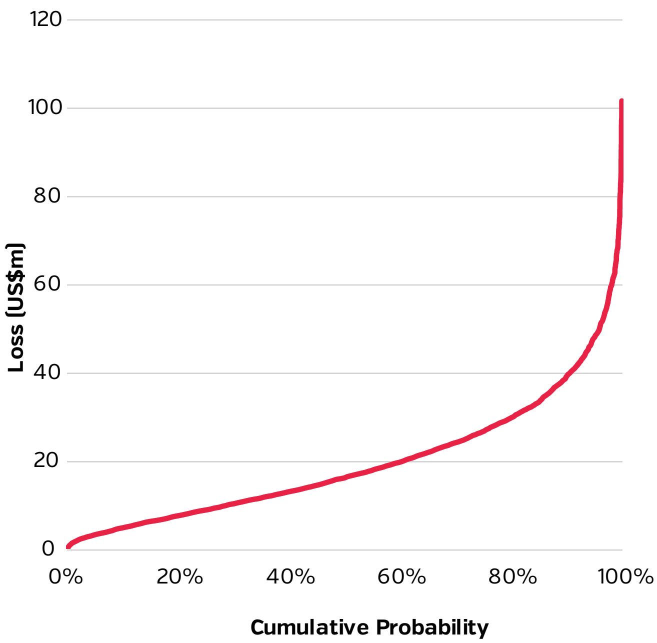
- In this sensitivity scenario, the reserve covers losses up to the 1 in 3.1 year return period and contingent credit covers losses between the 3.1 year and 7.2 year return period.
- Strategy B is still the cheapest on average and at the 1 in 5 and 1 in 30 year return periods, because the layer of losses financed by contingent credit (up to the 7.2 year loss) is still significantly lower than the layer of losses financed by insurance (up to the 30 year loss), with the remainder financed by the more expensive post-disaster debt.
- However, compared to the base scenario, the savings offered by Strategy B compared to Strategy A are decreased, because there is not as much post-disaster debt required in Strategy A (which drove up the overall cost in the base scenario).
- Similarly, the savings offered by Strategy C compared to Strategy A are decreased compared to the base scenario, due to the lower level of post-disaster debt required.

Country X Annexes

Annex X1 – Contingent Liability

Figure AX1.1 demonstrates the cumulative distribution function of poverty losses caused by reduced crop yields that arise from all perils. This cumulative distribution function of the contingent liability demonstrates a long tail of extreme potential losses.

Figure AX1.1 – Cumulative Distribution Function of the Yield Loss Due to All Perils



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Annex X2 – Assumptions

Reserve fund assumptions (all strategies)

Under all strategies, initial losses are retained through a reserve fund. The base case assumes that the reserve fund is assumed to be equal to US$20m, which is equal to a 1 in 2.5 year event.

The cost of reserve funds reflects the assumption that Country X has to borrow to fund the reserves and has to pay interest on the amount borrowed. While this is offset by the investment returns achieved on the reserves, the investment returns are typically assumed to be lower than the borrowing rate. The economic assumptions required for calculating the cost of reserve fund are therefore:

- Discount rate used to discount costs incurred in the future into present day terms
- Interest rate on amounts that are borrowed to fund reserves

- Investment return earned on reserve not used to fund losses.

The interest rate charged on amounts borrowed to fund the reserves is assumed to be 5 percent.

The fund is assumed to be invested in low risks assets, hence it is assumed that the investment return earned is equal to the borrowing rate, minus a spread of 2 percent.

For simplicity, it is assumed that the discount rate is the same as the borrowing rate – varying this assumption does not have a material effect on any conclusions drawn in this case study.

Post-disaster debt assumptions (all strategies)

Delay factor for post-disaster debt response: This is the impact on costs due to a delay in providing response (for example, due to reliance on slow finance instruments such as post-disaster debt). Currently this is assumed to be equivalent to a factor of 3, such that US$1 early (immediate financing of flood losses) is equivalent to US$3 late (post-disaster debt-financed). A factor of 3 is assumed in line with recent World Bank research.

Insurance assumptions (Strategy B)

Strategy B assumes that insurance will start to pay out once the reserve fund has been exhausted. The base case insurance contract structure is defined as follows:

- **Insurance Coverage:** The attachment point is 1 in 2.5 year loss when the reserve fund is exhausted. The insurance layer is assumed to cover losses up to the 1 in 30 year event (equivalent to US$52.4m).
- **Insurance Premium:** The annual premium payable is US$6.7m for all perils cover. The assumed premium was set using a pricing multiple of 1.35, which is representative of the perils insured at the time of writing this paper. Fees and expenses associated with insurance mechanisms are assumed to be included within the premium.

Budget reallocation assumptions (Strategy C)

Strategy C assumes that once the reserve fund has been exhausted, Country X will reallocate existing budgets to fund the losses. The base case assumes that Country X is able to reallocate budgets equal to US$20m, such that, together with the reserve fund, the maximum budget available to finance losses is US$40m (equivalent to a 1 in 10.7 year event).

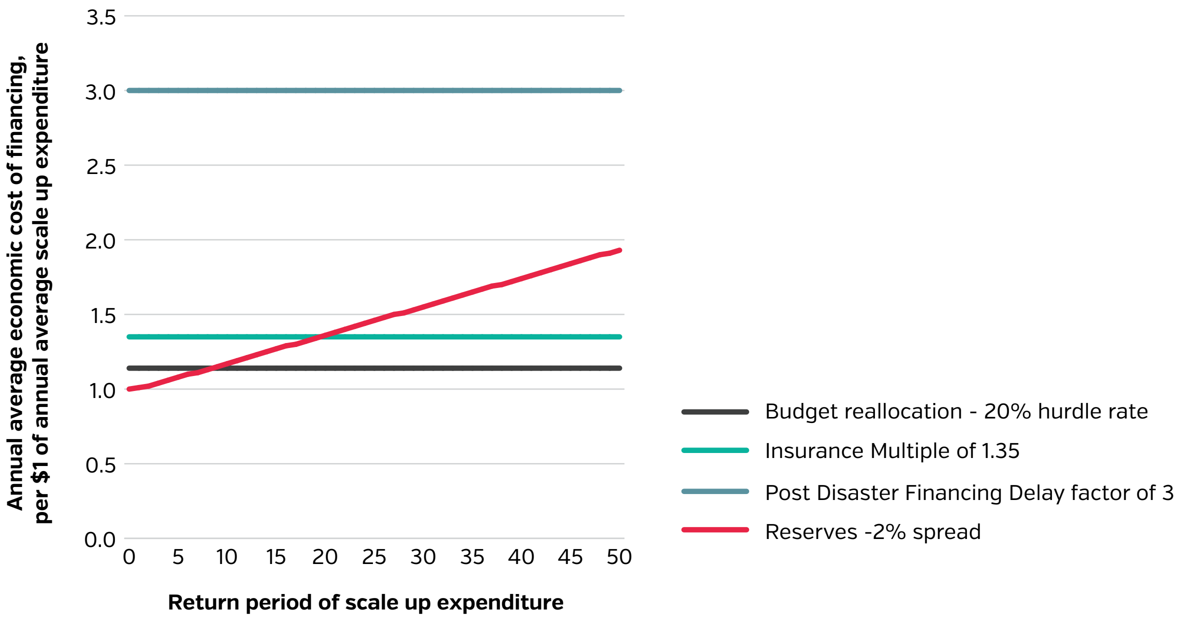
It is assumed that the cost of reallocating budgets is 20 percent.

Annex X3 – Sensitivity Analysis: Economic and Financial Assumptions

Marginal cost – base case scenario

Figure AX3.1 compares the marginal cost (as a multiple of expected loss in layer) for the various finance sources under the base case assumptions. The marginal cost represents the additional cost of each risk finance instrument per unit of annual average loss in layer, for a specific return period.

Figure AX3.1 – Marginal Cost as a Multiple of Loss, Base Case Assumptions



Source: Clarke, Cooney, Edwards, and Jinks (2016).

- The reserve fund has an increasing marginal cost due to the difference between the cost of borrowing funds (the interest rate) and the investment return earned on funds held in reserves, which is lower. At losses at higher return periods, the reserve fund is less likely to be called on and therefore more likely to incur a cost of holding funds.
- Post-disaster debt has a cost of exactly 3 times the loss at all return periods by definition of the delay factor of 3. It is assumed that US$1 of aid provided early costs US$3 when the response is provided late.
- Insurance has a cost of 1.35, reflecting the constant assumed 1.35 insurance pricing multiple.
- Budget reallocation has a constant marginal cost of 1.14 under the base case scenario, representing the spread between the hurdle rate (20 percent) and the discount rate (5 percent).

The marginal cost does not reflect the limitations and budgetary constraints of various finance sources – most notably funds available through some instruments are cost-effective but very limited. The graph implies that theoretically, budget reallocation is most cost-effective for high finance cost return periods. However, this ignores the fact that there might be a limit on the extent to which government budgets can be reallocated.

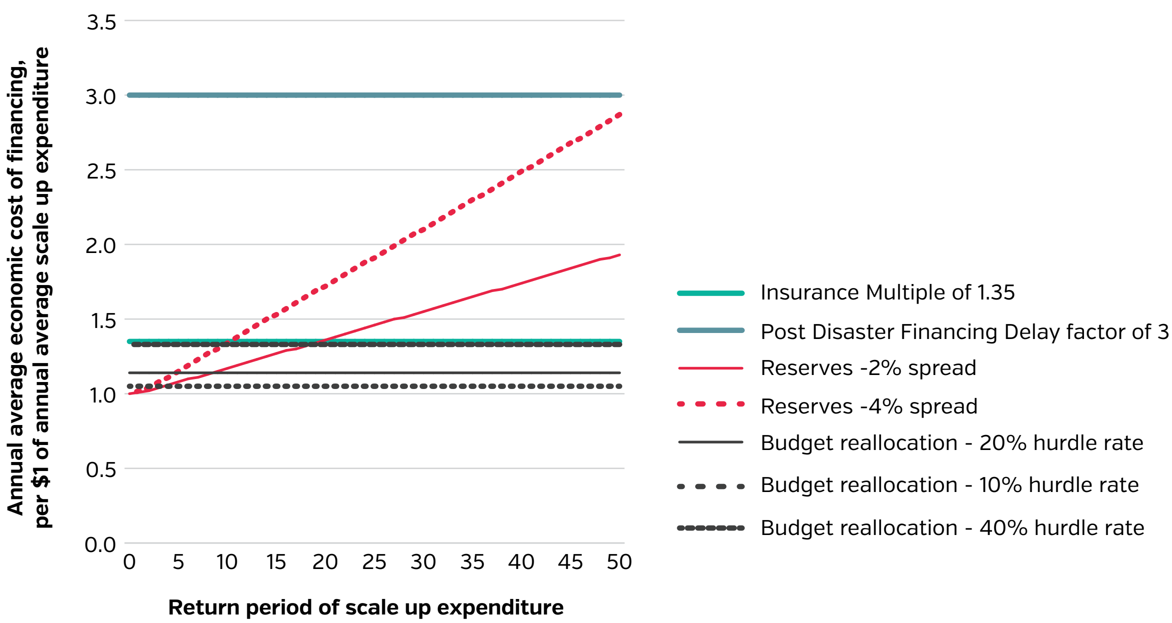
Where the different lines of marginal cost intersect is where one finance strategy becomes marginally more cost-effective than another:

- Reserves are the cheapest finance instrument up the 1 in 8.5 year return period.
- For losses greater than the 1 in 8.5 year loss, budget reallocation is always marginally the cheapest finance instrument.
- Reserves remain the second cheapest between the 1 in 8.5 year and the 1 in 19.4 year loss, after that insurance is the second cheapest.

Marginal cost - sensitivities

Figures AX3.2 and AX3.3 consider the impact on the marginal cost of adjusting economic and financial assumptions:

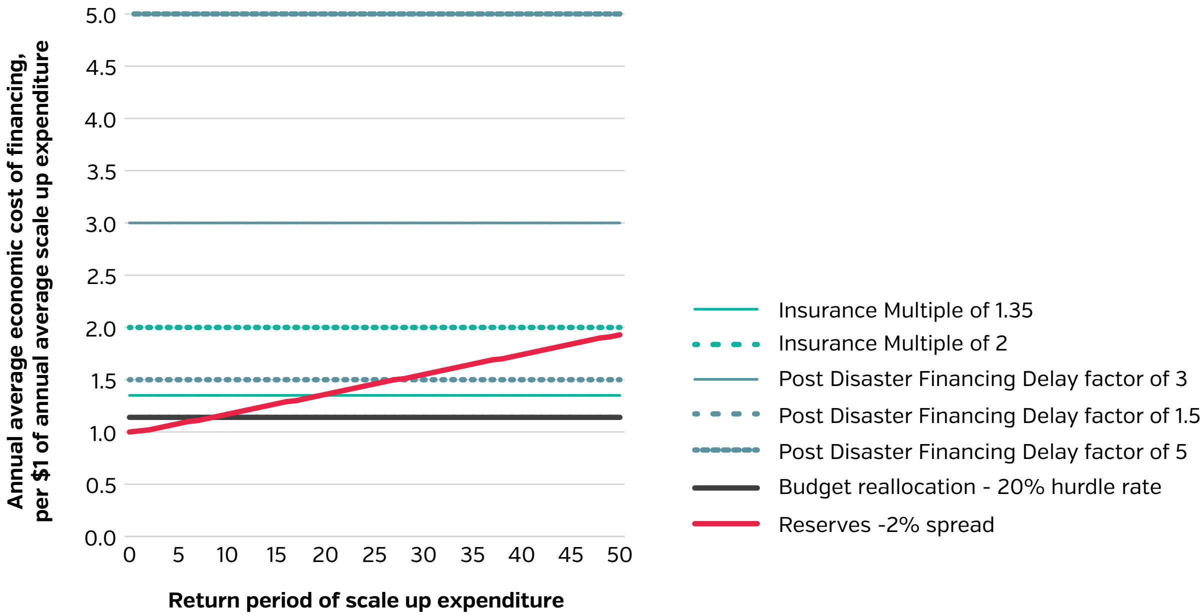
Figure AX3.2 – Marginal Cost as a Multiple of Loss, Sensitivity to the Spread on the Reserve Fund and budget Reallocation Hurdle Rate



Source: Clarke, Cooney, Edwards, and Jinks (2016).

- Increasing the spread between the interest rate and investment return of the reserve increases the slope of the marginal cost line, such that the reserve becomes less cost-effective.
- Similarly, increasing (decreasing) the budget reallocation hurdle rate increases (decreases) the marginal cost of budget reallocation and increases (decreases) the point to which the reserves remain the cheapest instrument.

Figure AX3.3 – Marginal Cost as a Multiple of Loss, Sensitivity to the Post-Disaster Debt Delay Factor and the Insurance Multiple



Source: Clarke, Cooney, Edwards, and Jinks (2016).

- Increasing the insurance pricing multiple increases the point at which insurance becomes marginally the least cost-effective strategy compared to reserves and budget reallocation. In fact, increasing the multiple to 2 means that the reserve fund and budget reallocation always has a lower marginal opportunity cost than insurance.
- Increasing the post-disaster finance delay factor shifts up the horizontal line showing the post-disaster finance cost, such that it is now significantly more expensive than the other strategies.

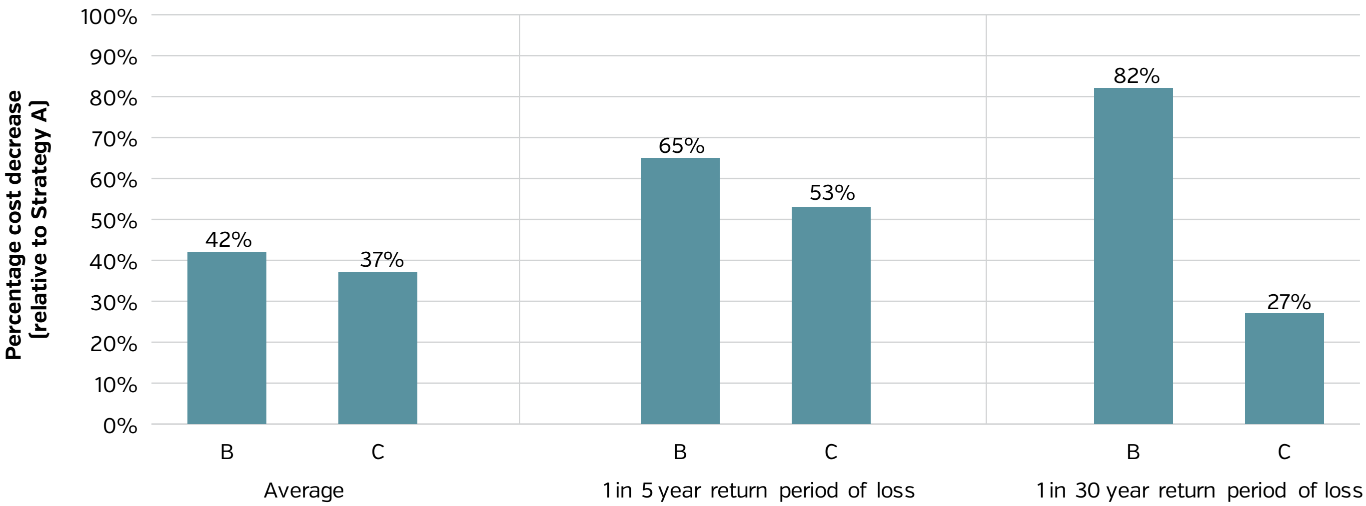
Annex X4 – Sensitivity Analysis: Varying Maximum Funding by Finance Instrument

Reduced reserve fund coverage

Figure AX4.1 and AX4.2 show the cost of the three strategies above over different return periods, assuming the reserve fund is reduced to US$10m (1 in 1.4 year return period). For the alternative finance strategies considered:

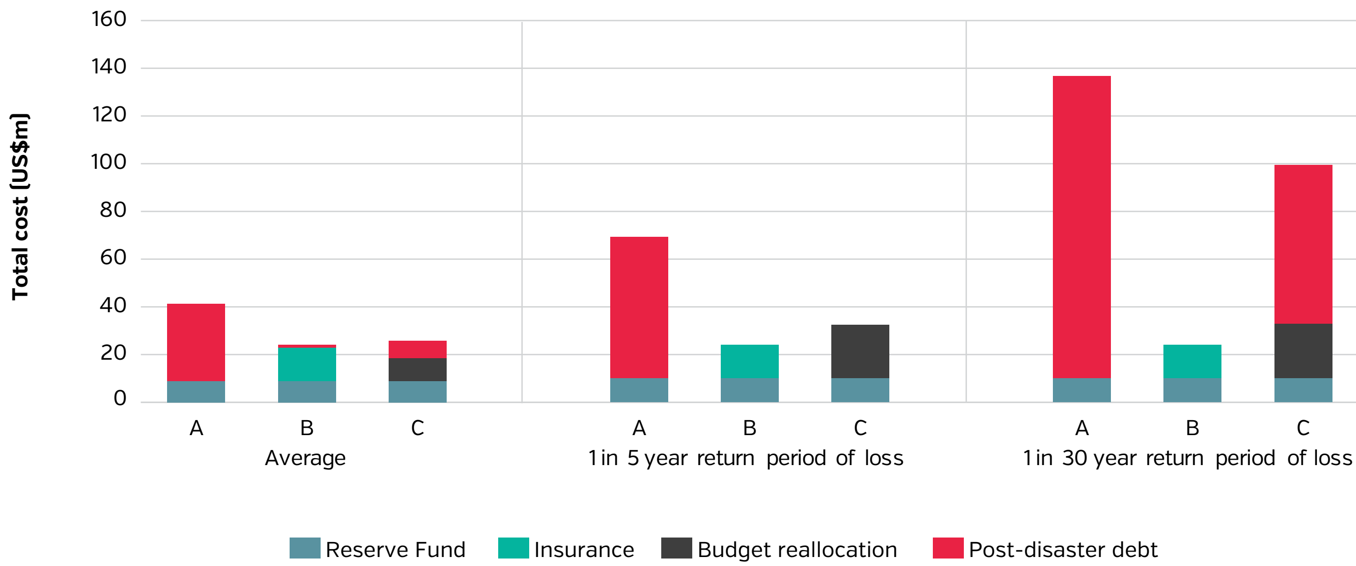
- Strategy B assumes that insurance still attaches after the reserve fund and is assumed to cover losses up to the 1 in 30 year event.
- Strategy B assumes that the government is still able to reallocate budgets equal to US$20m, such that, together with the reserve fund, the maximum budget available to finance losses is US$30m (equivalent to a 1 in 5.1 year event).

Figure AX4 .1 – Relative Cost Saving of Reduced Reserve Fund



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Figure AX4.2 – Total Cost of Reduced Reserve Fund



Source: Clarke, Cooney, Edwards, and Jinks (2016).

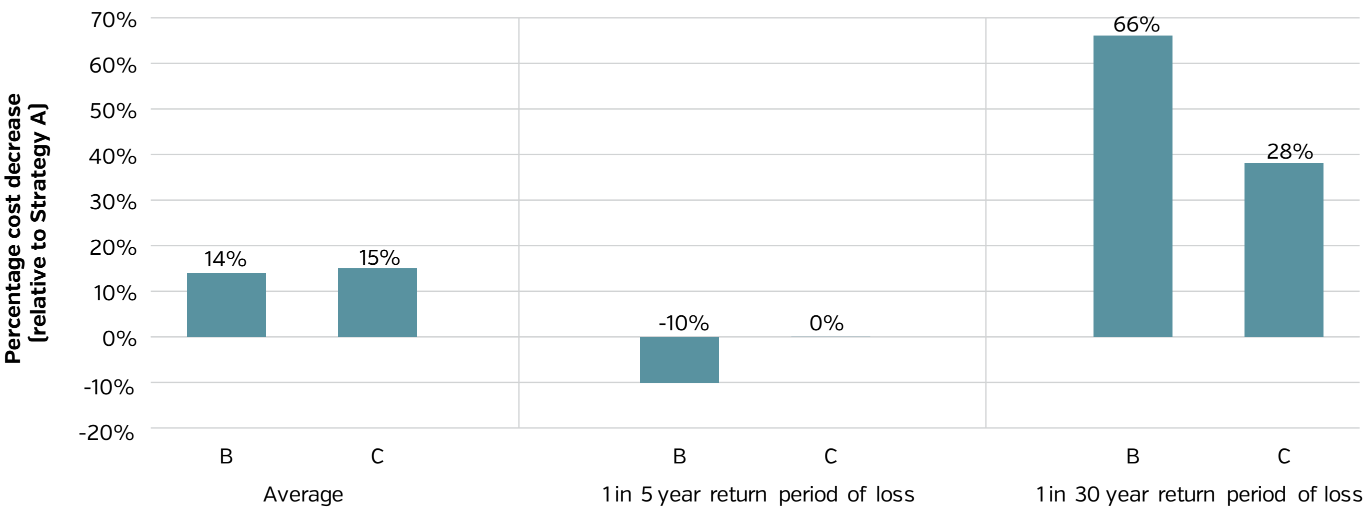
- Decreasing the reserve fund increases the average costs for all three strategies as there are more losses met from post-disaster debt in Strategies A and C (which is the least cost-effective strategy) and there is an increase in the premium in Strategy B.
- Strategy B is still the cheapest, both on average and at the return periods considered. Decreasing the reserve fund increases the cost savings of Strategy B relative to Strategy A as the additional losses previously covered by the reserve fund are ceded to the insurer (at the marginal cost of the assumed insurance price multiple of 1.35), which is cheaper than the additional losses covered by post-disaster debt (at a marginal cost of the assumed delay factor of 3).
- Strategy C is still cheaper than Strategy A, but the relative savings at the higher return periods are reduced as post-disaster debt begins to dominate the total cost of both strategies.

Increased reserve fund coverage

Figure AX4.3 and AX4.4 show the cost of the three strategies above over different return periods, assuming that the reserve fund is increased to US$30m (1 in 1.4 year return period). For the alternative finance strategies considered:

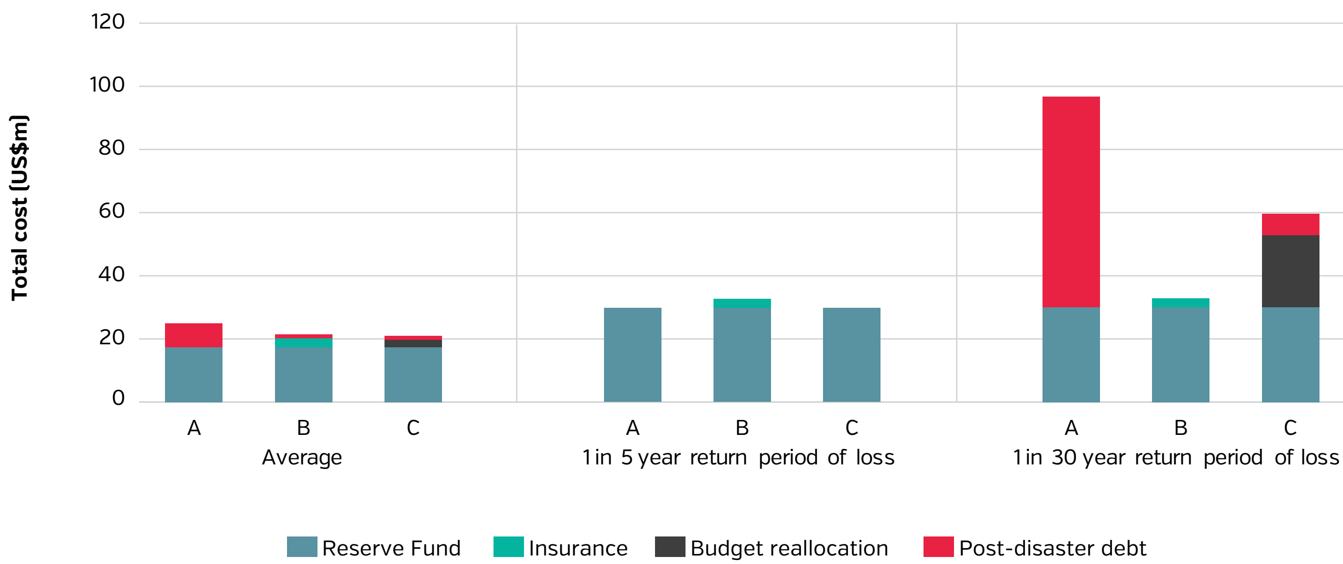
- Strategy B assumes that insurance still attaches after the reserve fund and is assumed to cover losses up to the 1 in 30 year event.
- Strategy C assumes that the government is still able to reallocate budgets equal to US$20m, such that, together with the reserve fund, the maximum budget available to finance losses is US$50m (equivalent to a 1 in 24.7 year event).
- Increasing the reserve reduces the average costs for all three strategies as there are more losses met from the reserve in all strategies, which is the most cost-effective strategy at lower return periods.
- While Strategy B is still the cheapest on average, at the 1 in 5 return period Strategy A is now more cost-effective. This is because the reserve is sufficient to meet 1 in 5 year events and hence the insurance is not called on but the premium is still payable.
- As in the baseline assumptions, costs at the 1 in 5 year period are higher than the average costs for all strategies. This is because the average loss under the assumed distribution is smaller than the 1 in 5 year loss (see Annex 1 for the assumed distribution of losses).
- At the 1 in 5 return period, the cost of Strategy A and C are identical because there is no need for budget reallocation.
- At higher return periods, Strategy B is still the cheapest strategy.

Figure AX4 .3 – Relative Cost Saving of Increased Reserve Fund



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Figure AX4.4 – Total Cost of Increased Reserve Fund



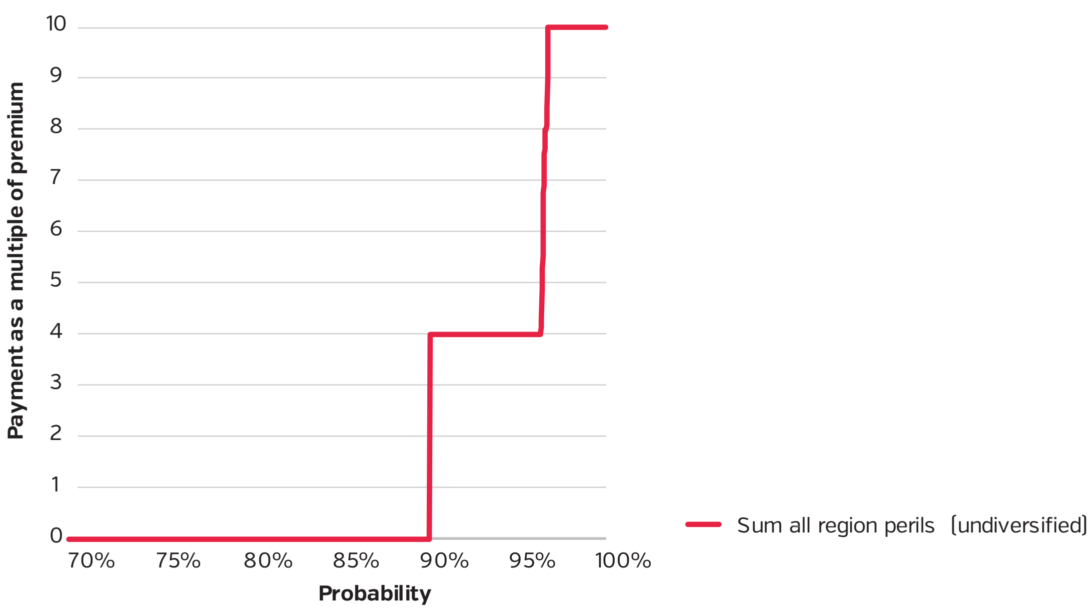
Source: Clarke, Cooney, Edwards, and Jinks (2016).

Country Y Annexes

Annex Y1 – Underlying Contingent Liability

Figure AY1.1 represents the undiversified total payout/cost function in Strategy A. There is a discrete increase at approximately 90 percent to a multiple of 4 times the premium. This is consistent with the fact the initial payout is triggered at the 1 in 10 return period, which corresponds to a 90th percentile (slightly greater for some regions due to multiple events occurring in one year). There is a plateau at payouts of 10 times the premium after approximately the 96.7th percentile (corresponding to 1 in 30), with a step in between of 8 times the premium for years with multiple events.

Figure AY1.1 – Cumulative Distribution Function for Undiversified Total Payouts/Costs



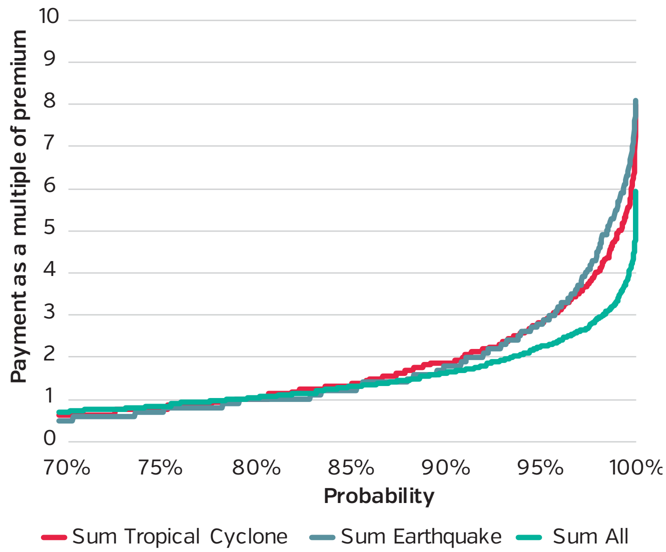
Source: Clarke, Cooney, Edwards, and Jinks (2016).

Figure AY1.2 demonstrates the diversified individual distributions, summed by simulated year. Some correlation exists between neighbouring regions, as expected, but there is an overall diversification benefit.

The pooled portfolio demonstrates an overall smoother loss function profile, with sharp increase to a total aggregate 10 times the premium loss; that is, even the 1 in 200 loss at the 99.5th percentile is significantly lower than the maximum loss (unlike in Figure AY1.1, where the 1 in 200 loss is also the maximum loss).

Figure AY1.2 – Cumulative Distribution Functions for Pooled Cover (by Peril and in Aggregate)

	Individual Insurance Contracts	Pooled Earthquake Only	Pooled Tropical Cyclone Only	Fully Pooled
1 in 200 loss (as multiple of base premium)	10	6.3	5.4	3.8
Maximum simulated (1 in 10,000) loss (as multiple of base premium)	10	8.1	8.0	5.9



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Annex Y2 – Base Case Scenario Assumptions

Economic assumptions

Initial payouts (in Strategy C) are retained through a reserve fund.

The cost of reserve funds reflects the assumption that Country Y has to borrow to fund the reserves and has to pay interest on the amount borrowed. While this is offset by the investment returns achieved on the reserves, the investment returns are typically assumed to be lower than the borrowing rate. The economic assumptions required for calculating the cost of reserve fund are therefore:

- Discount rate used to discount costs incurred in the future into present day terms
- Interest rate on amounts that are borrowed to fund reserves
- Investment return earned on reserve not used to fund payouts.

The retained payouts are assumed to be fully capitalised; that is, the pooled facility is assumed to hold capital reserves at a level equal to the maximum expected payout in the retained layer. For simplicity and because the focus of this case study is on different insurance strategies, the discount rate, interest rate, and investment return are assumed to all be equal. The simplifying result of this combination of assumptions is that the cost of financing the retained payouts is equal to the costs occurred in the retained layer, with no cost charged on the capital reserves held in excess of the loss incurred.

Risk transfer assumptions

Under Strategy A the average insurance pricing multiple based on the individual insurance contracts is 1.64 (determined based on the premium divided by the average annual loss).

Two key assumptions were made in comparing the insurance price of Strategies B and C:

- Diversification benefit (Strategy B): The diversification benefit that can be achieved by moving from Strategy A to Strategy B and pooling the risks of all regions
- Reinsurance pricing (Strategy C): The (re)insurance pricing multiple applied to excess losses in Strategy C.

Strategy B diversification benefit

Based on a pool of the cumulative underlying risk, the resulting cumulative distribution function (CDF) follows a smoother distribution (than the individual risks) and there is a diversification benefit arising from the pooling of all risks. This is demonstrated in Figure AY1.2 in Annex Y1.

With the evidence that a diversification benefit exists, assumptions were made about the size of this benefit (that is, the discount on premiums charged) through consideration of the following metrics:

- The insurance pricing multiple (premium divided by average annual loss)
- The implied risk volatility loading to demonstrate the premium charged to compensate for the level of volatility in the underlying losses (see Glossary).

Strategy A assumes a summation of all CDFs across all regions and perils with no diversification benefit (see Figure AY1.1 in Annex Y). Strategy B has an inherent diversification benefit incorporated, as it is summing across 13 regions by simulated year rather than by CDF ranked from best scenario (no losses) to worst scenario (maximum payout for each region). Some correlation exists between neighbouring regions, as expected, but there is an overall diversification benefit (see Figure AY1.2 in Annex Y1). Therefore, as a starting point, comparing Strategy B with Strategy A, it is intuitively expected that:

- The risk volatility loading to be higher: This is because Strategy A would have a relatively high standard deviation value due to the nature of the defined payouts being a step function with a more extreme maximum than any pooled loss distributions in Strategies B. A relatively greater standard deviation value would result in a relatively lower risk volatility loading base amount.
- The pricing multiple to be lower, due to the diversification benefit achieved in Strategy B.

The initial parameter for the diversification benefit from Strategy B was set as 10 percent:

- It is evident that there should be some level of diversification, but without real-time market pricing insight it is difficult to set an initial parameter. Ten percent was chosen for simplicity and to demonstrate the difference in cost between Strategy A and B.
- It is intuitive that any diversification benefit greater than 2.5 percent (which is the additional fee charged for pooling) will result in Strategy B being more cost-effective.
- While this approach may not be robust enough for market pricing purposes, it is sufficient for the purposes of the evaluation of the finance strategies in this case study and will allow us to reach a reasonable conclusion, keeping the limitation on parameter robustness in mind.

Strategy C pricing multiple

The resulting assumption for the pricing multiple in Strategy C was set based on a reasonable level of the risk volatility loading compared to Strategy B. The pricing multiple is expected to be greater in Strategy C than Strategy B due to the higher layer of risk being written and the greater volatility in the layer.

A summary of the base case scenario assumptions and diagnostics are outlined in Table AY2.2.

Table AY2.2 – Diagnostics of Insurance Pricing Assumptions, Base Case

	Strategy A	Strategy B	Strategy C
Diversification benefit		10%	
Pricing multiple	1.64	1.47	2.00
Risk volatility loading	52%	38%	25%

Source: Clarke, Cooney, Edwards, and Jinks (2016).

Market and administration fees

There are fees assumed to be placed on the risk transfer mechanisms:

- Strategy B and C both have a 2.5 percent market fee charged on the premium for the layer placed in the insurance market.
- Strategy C has a 5 percent administrative fee charged on the retained layer.

Annex Y3 – Sensitivity Analysis

The analysis considered sensitivities to key assumptions as follows:

- Strategy B diversification benefit: increase from 10 percent to 20 percent
- Strategy C insurance pricing multiple: reduce from 2.0 to 1.47
- Strategy C economic assumptions relevant to the risk retention: increase the spread (between the interest rate and investment return) from 0 percent to 5 percent.

For the first two sensitivities, the insurance pricing assumptions are considered, in Table AY3.1 were considered which decrease the cost of insurance premiums in both Strategy B and C, as outlined by the resulting pricing multiples in Table AY3.1.

Table AY3.1 – Diagnostics of Insurance Pricing Assumptions, Sensitivities

	Strategy A	Strategy B - sensitivity	Strategy C - sensitivity
Diversification benefit	N/A	20%	N/A
Pricing multiple	1.64	1.31	1.47
Risk volatility loading	52%	25%	12%

Source: Clarke, Cooney, Edwards, and Jinks (2016).

For the third sensitivity, the following dynamics with the economic assumptions apply:

- Increasing the discount rate and/or decreasing the investment rate (that is, increasing the spread between the investment rate and the discount rate) will increase the cost. To demonstrate this, a spread of 5 percent (such that the discount rate is 5 percent higher than the investment rate) is assumed.

Additional parameters and sensitivities that have not been considered are outlined in Table AY3.2.

Table AY3.2 – Assumptions with Sensitivity Analysis Not Considered

<table>
<tr><th>Assumption</th><th>Base Parameter</th><th>Justification for Not Considering Sensitivity Analysis</th></tr>
<tr><td>Spread between interest rate & discount rate</td><td>0% (interest rate = 4%; discount rate = 4%)</td><td>No sensitivity analysis considered as a more material and relevant spread is the one between investment return and interest rate.</td></tr>
<tr><td>Market fee</td><td>2.5%</td><td rowspan="2">The magnitude of how much these assumptions will vary is likely to be significantly smaller than the assumptions around premium pricing for Strategy B and C.

The direction of movement in overall cost is intuitively obvious and there is minimal additional insight to be gained in varying these assumptions – the costs will increase proportionally and evenly for all return periods (since premiums are consistent) as the fees increase.</td></tr>
<tr><td>Administration fee</td><td>5%</td></tr>
</table>

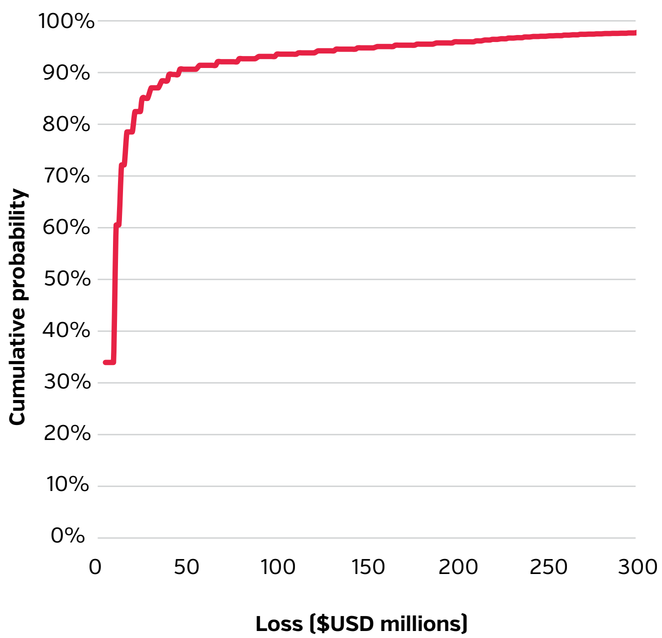
Country Z Annexes

Annex Z1 – Contingent Liability

Figure AZ1.1 demonstrates the cumulative distribution function of the public capital losses relating to tropical cyclone damage. This cumulative distribution function of the contingent liability demonstrates a long tail of extreme potential losses, which is the nature of catastrophic tropical cyclone exposure. It is the same shape as the underlying total tropical cyclone losses (the losses are just a 30 percent proportion of total tropical cyclone losses).

Public capital losses have been capped at the 1 in 50 year return period (approximately US$300m or 2.5 percent of GDP). Losses beyond this magnitude are assumed to require significant donor support in any finance strategy – the cost of this donor support would be consistent for all strategies and is excluded from this analysis.

Figure AZ1.1 – Cumulative Distribution Function of the Public Losses



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Annex Z2 – Assumptions

Reserve fund assumptions (all strategies)

Under all strategies, initial losses are retained through a reserve fund. The base case assumes that the reserve fund is assumed to be equal to 0.2 percent of GDP, which is broadly equivalent to a 1 in 6 year event.

The cost of reserve funds reflects the assumption that Country Z has to borrow to fund the reserves and has to pay interest on the amount borrowed. While this is offset by the investment returns achieved on the reserves, the investment returns are typically assumed to be lower than the borrowing rate. The economic assumptions required for calculating the cost of reserve fund are therefore:

- Discount rate used to discount costs incurred in the future into present day terms
- Interest rate on amounts that are borrowed to fund reserves
- Investment return earned on reserve not used to fund finance costs.

The interest rate charged on amounts borrowed to fund the reserves is assumed to be 6.75 percent, which is the yield on long-term bonds issued by Country Z in US$.

The fund is assumed to be invested in low risk assets, hence it is assumed that the investment return earned is equal to the borrowing rate, minus a spread of 3 percent.

For simplicity, it is assumed that the discount rate is the same as the borrowing rate – varying this assumption does not have a material effect on any conclusions drawn in this case study.

Post-disaster debt assumptions (all strategies)

All strategies assume that large losses (that is, those that exhaust the additional financial instruments described below) are met by post-disaster debt issued by Country Z. A post-disaster debt delay factor of 18.44 percent is assumed based on assumptions that:

- Emergency public losses account for 23 percent of losses.
- The internal rate of return for emergency public losses is 40 percent.
- The internal rate of return for non-emergency public losses is 12 percent.
- There is a one-year delay in building both emergency and non-emergency reconstruction.

Insurance assumptions (Strategy B)

Strategy B assumes that insurance will start to pay out once the reserve fund has been exhausted. The base case insurance contract structure is defined as follows:

- **Insurance Coverage:** The attachment point is 1 in 6 year loss when the reserve fund is exhausted. The insurance layer is assumed to cover losses up to the 1 in 30 year event.

- **Insurance Premium:** The annual premium payable is US$23.5m for tropical cyclone cover. The assumed premium was set with consideration of the following metrics:
  - The pricing multiple (premium divided by annual average loss)
  - The implied risk volatility loading to demonstrate the premium charged to compensate for the level of volatility in the underlying losses (see Glossary).

The base case assumes a constant risk volatility loading of 25 percent. For the assumed attachment point and layer, this is equivalent to a pricing multiple of 1.85. It should be noted that if the risk volatility loading is assumed to be constant then the equivalent pricing multiple increases (decreases) as the assumed attachment point increases (decreases) and the assumed layer decreases (increases). This is because the volatility of insured losses increases as the attachment point increases, and hence insurers charge a higher premium for the extra volatility.

Fees and expenses associated with insurance mechanisms are assumed to be included within the premium.

Budget reallocation assumptions (Strategy C)

Strategy C assumes that once the reserve fund has been exhausted, Country Z will reallocate existing budgets to fund the losses. The base case assumes that Country Z is able to reallocate budgets equating to 0.8 percent of GDP, such that, together with the reserve fund, the maximum budget available to finance losses is 1 percent of GDP (roughly equivalent to a 1 in 17 year event).

It is assumed that the cost of reallocating budgets is 37 percent, based on economic modelling.

Contingent credit assumptions (Strategy D)

Strategy D assumes that Country Z has contingent credit arrangements to provide immediate liquidity in the aftermath of a tropical cyclone event.

It is assumed that Country Z can secure contingent credit of up to a maximum of US$30m, which is approximately 0.25 percent of GDP, consistent with current World Bank arrangements.[1]

To derive the cost of contingent credit, it is assumed that Country Z would otherwise have to borrow the amount of the line of contingent credit from the commercial market (at the government's ex-ante borrowing rate) in order to finance the same portfolio of expenditures.

As a result, the cost of contingent credit depends not only on the assumed contingent credit interest rate but also the spread between the interest rate on amounts borrowed and the contingent credit interest rate.

The economic assumptions required for calculating the cost of contingent credit are therefore:

- Discount rate used to discount costs incurred in the future into present day terms
- Interest rate on amounts that are borrowed (the ex-ante borrowing rate)
- The interest rate charged on contingent credit.

Contingent credit interest rates, such as catastrophe risk deferred drawdown options are set based on a spread over LIBOR. Based on current US$ LIBOR rates and IBRD lending rates, a contingent credit interest rate of 2.5 percent is assumed.

1 http://treasury.worldbank.org/bdm/pdf/Handouts_Finance/CatDDO_Product_Note.pdf

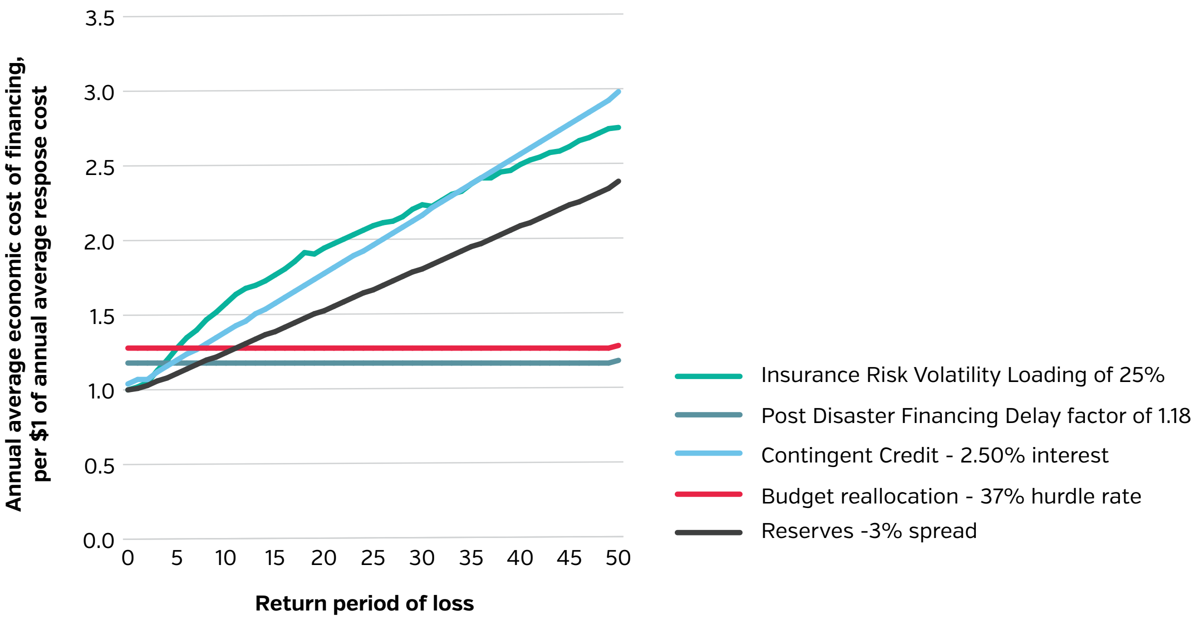
In addition to the contingent credit interest rate, contingent credit arrangements such as catastrophe risk deferred drawdown options charge fees for establishing these lines of credit. For simplicity, a single front-end fee of 0.5 percent of the maximum loan amount is assumed.

Annex Z3 – Sensitivity Analysis: Economic and Financial Assumptions

Marginal cost – base case scenario

Figure AZ3.1 compares the marginal cost (as a multiple of expected loss in layer) for the various financial instruments under the base case assumptions. The marginal cost represents the additional cost of each risk finance instrument per unit of annual average loss in layer, for a specific return period.

Figure AZ3.1 – Marginal Cost as a Multiple of Loss, Base Case Assumptions



Source: Clarke, Cooney, Edwards, and Jinks (2016).

- The reserve fund has an increasing marginal cost due to the difference between the cost of borrowing funds (the interest rate) and the investment return earned on funds held in reserves, which is lower. For losses at higher return periods, the reserve fund is less likely to be called on and therefore more likely to incur a cost of holding funds.
- Contingent credit similarly has an increasing marginal cost due to the difference between the cost of borrowing funds (interest/discount rate) and the investment return earned on the amount of contingent credit unused, which is lower. This spread (4.25 percent being the difference between 6.75 percent and 2.5 percent) is greater than for the reserve fund and so the marginal cost increases more sharply.

- Post-disaster debt has a cost of 1.18 times the loss at all return periods.
- Budget reallocation has a constant marginal cost of approximately 1.30 under the base case scenario, with 30 percent being approximately the spread between the hurdle rate (37 percent) and the discount rate (6.75 percent).
- The marginal cost for insurance is derived from the change in insurance premium that results from insurance attaching US$1 higher. Attaching insurance at a higher return period increases the marginal cost of insurance (note that the unsmooth curve of the insurance marginal cost is a result of the number of simulations used). This is because a constant risk volatility loading is assumed and as the attachment point increases, the uncertainty in the loss increases. When expressed relative to the loss amount, it is therefore cheaper for insurance to attach at a lower level.

The marginal cost does not reflect the limitations and budgetary constraints of various financial instruments – most notably funds available through some instruments (for example, contingent credit) are cost-effective but very limited. The graph implies post-disaster debt is most cost-effective for high loss return periods.

Where the different lines of marginal cost intersect is where one finance strategy becomes marginally more cost-effective than another:

- Reserves are the cheapest finance instrument up the 1 in 7.6 year return period.
- For losses greater than the 1 in 7.6 year loss, post-disaster debt financing is always marginally the cheapest finance instrument.
- Reserves remain the second cheapest between the 1 in 7.6 year and the 1 in 11.1 year loss, after that budget reallocation is the second cheapest.
- Beyond the 1 in 5 year, insurance and contingent credit are marginally the most expensive finance instruments (assuming that insurance attaches at these higher return periods).

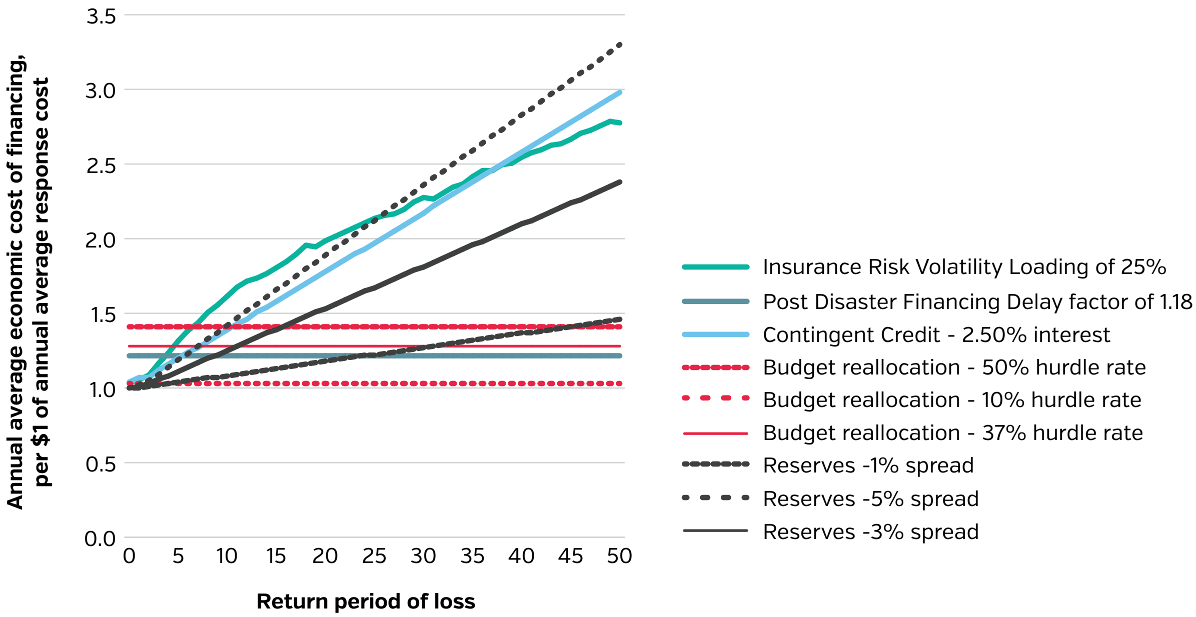
Note that the last bullet may at first sight appear inconsistent with Figure Z3.4, which shows that at higher return periods, Strategy B (insurance) is the cheapest strategy. This is because the marginal cost presented in Figure AZ3.1 assumes that insurance attaches at the return period shown on the x-axis.

In our baseline assumptions, Strategy B assumes that insurance attaches at the 1 in 6 year loss. As a result, Strategy B 'locks in' the marginal cost of insurance at the 1 in 6 year level, which is much lower. Or alternatively, Figure AZ3.1 demonstrates that it is much more cost-effective for insurance to attach at lower return periods.

Marginal cost - sensitivities

Figures AZ3.2, AZ3.3 and AZ3.4 consider the impact on the marginal cost of adjusting the following economic and financial assumptions:

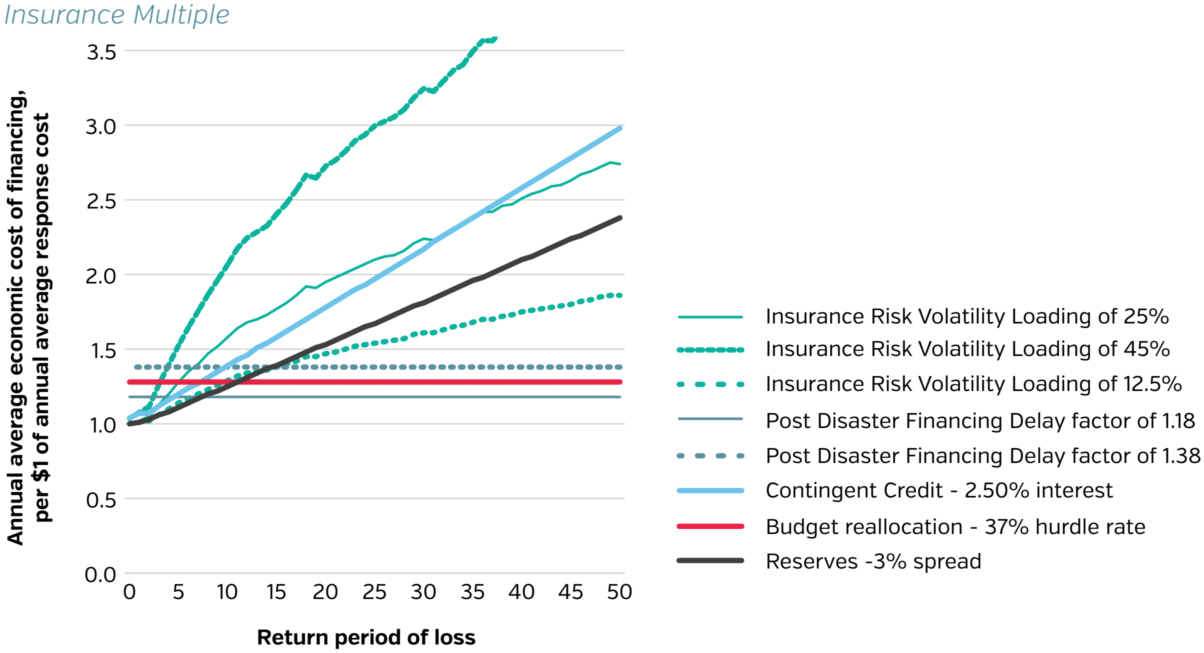
Figure AZ3.2 – Marginal Cost as a Multiple of Loss, Sensitivity to the Spread on the Reserve Fund and The Budget Reallocation



Source: Clarke, Cooney, Edwards, and Jinks (2016).

- Increasing (decreasing) the spread between the interest rate and investment return of the reserve increases (decreases) the slope of the marginal cost line, such that the reserve becomes less (more) cost-effective.
- Increasing (decreasing) the budget reallocation hurdle rate shifts up the horizontal line showing the budget reallocation marginal cost, such that budget reallocation becomes less (more) cost-effective.

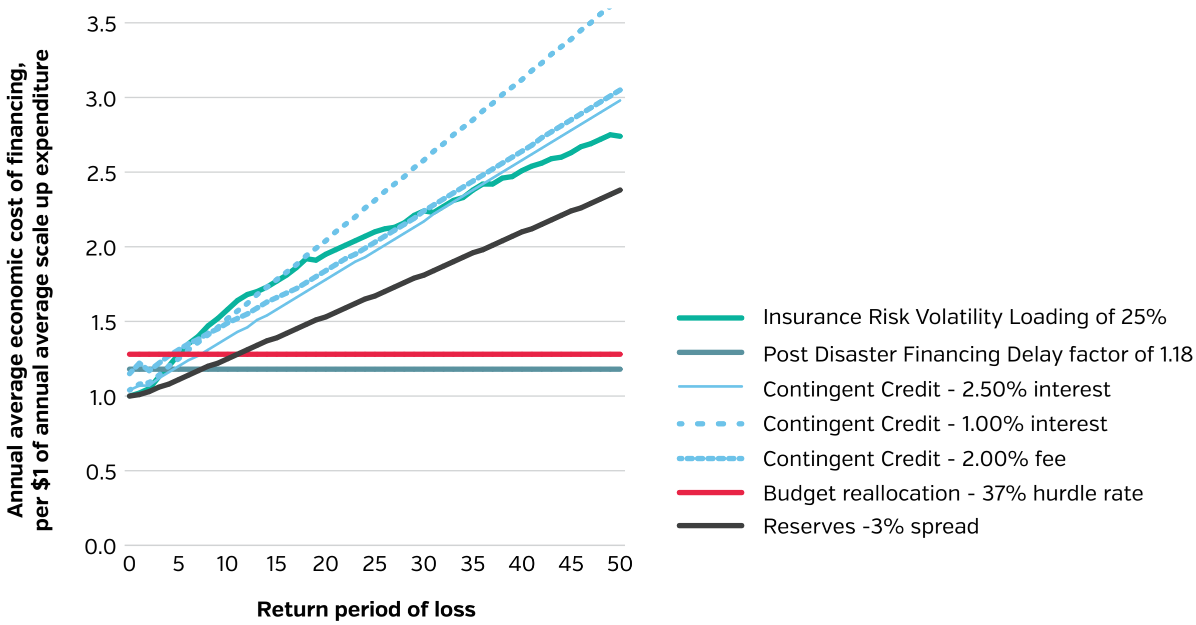
Figure AZ3.3 – Marginal Cost as a Multiple of Loss, Sensitivity to the Post-Disaster Debt Delay Factor and the Insurance Multiple



Source: Clarke, Cooney, Edwards, and Jinks (2016).

- Increasing (decreasing) the risk volatility loading decreases (increases) the point at which insurance becomes marginally the least cost-effective strategy.
- Increasing the post-disaster finance delay factor shifts up the horizontal line showing the post-disaster finance cost, such that it becomes a less cost-effective option.

Figure AZ3.4 – Marginal Cost as a Multiple of Loss, Sensitivity to the Contingent Credit Assumptions



Source: Clarke, Cooney, Edwards, and Jinks (2016).

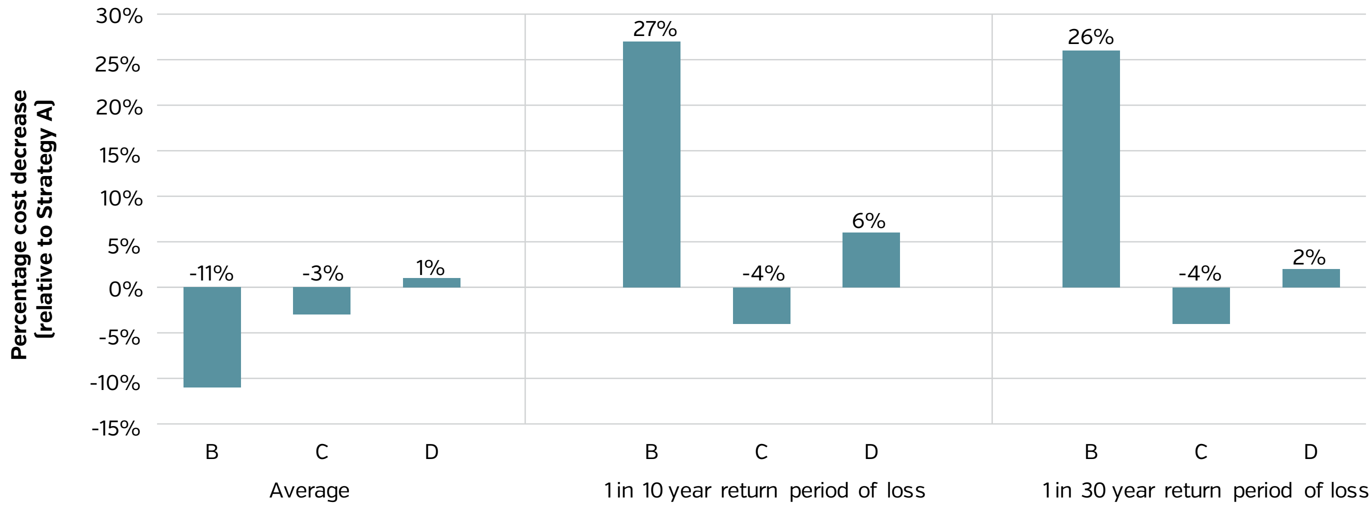
- Reducing the interest rate charged on contingent credit investment return increases the slope of the marginal cost line, such that contingent credit becomes less cost-effective.
- Increasing the fee to 2 percent of the contingent credit maximum, increases the marginal cost slightly, such that contingent credit becomes less cost-effective.

Annex Z4 – Sensitivity Analysis: Varying Maximum Funding by Finance Instrument

Reduced insurance layer

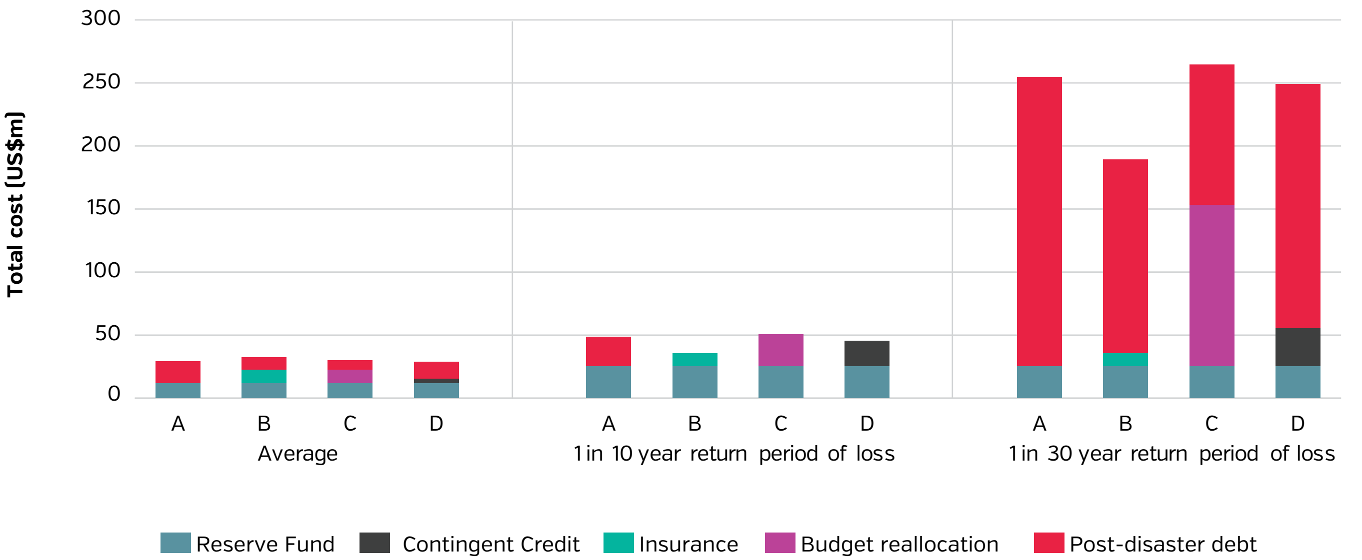
Figures AZ4.1 and AZ4.2 show the relative cost savings and overall costs of the four strategies over different return periods, assuming that the insurance layer covers only finance costs up to the 1 in 15 year return period.

Figure AZ4.1 – Relative Cost Saving of Reduced Insurance Layer



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Figure AZ4.2 – Total Cost of Reduced Insurance Layer



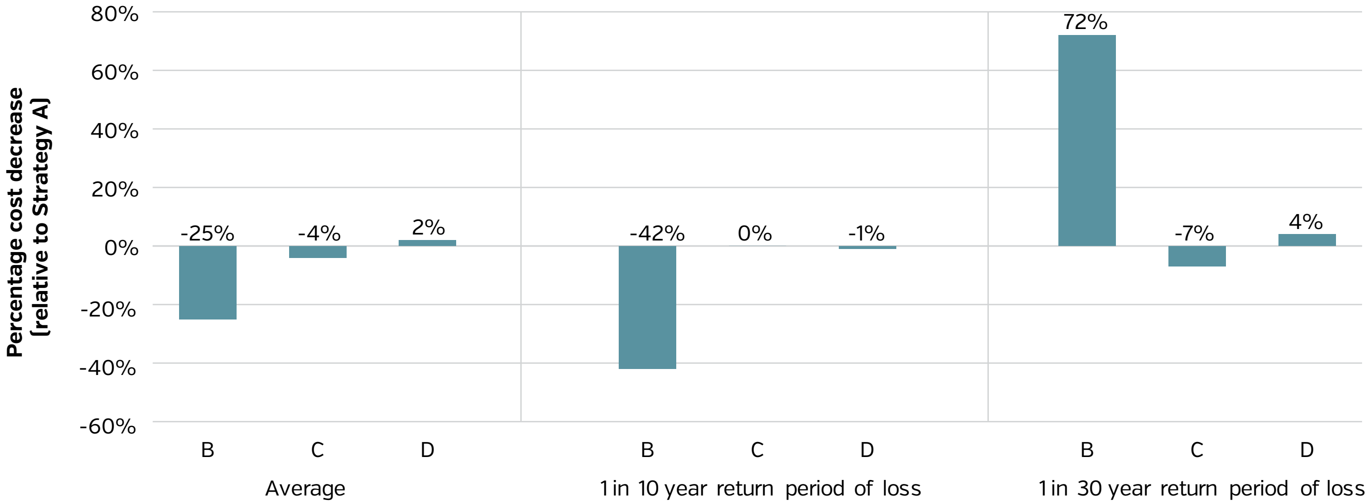
Source: Clarke, Cooney, Edwards, and Jinks (2016).

- Decreasing the insurance layer shows that at higher return periods, post-disaster debt is now required, hence increasing the total cost of Strategy B. While it is still cheaper than the other strategies at higher return periods, consistent with the base case scenario results, the saving is not as great due to the requirement for post-disaster debt.
- On average and at lower levels of losses, the total cost of Strategy B is now lower compared to the base case scenario as the premium has reduced. On average, Strategy B is still the most expensive (consistent with the base case scenario).
- At the 1 in 10 year return period Strategy B becomes more cost-effective strategy (contrary to the base case scenario where Strategy D was cheapest at this level of loss) since losses are fully covered up to the 1 in 10 year loss, but the premium is lower than the base case scenario premium (due to the overall reduced coverage).

Increase layers of non-insurance finance arrangements

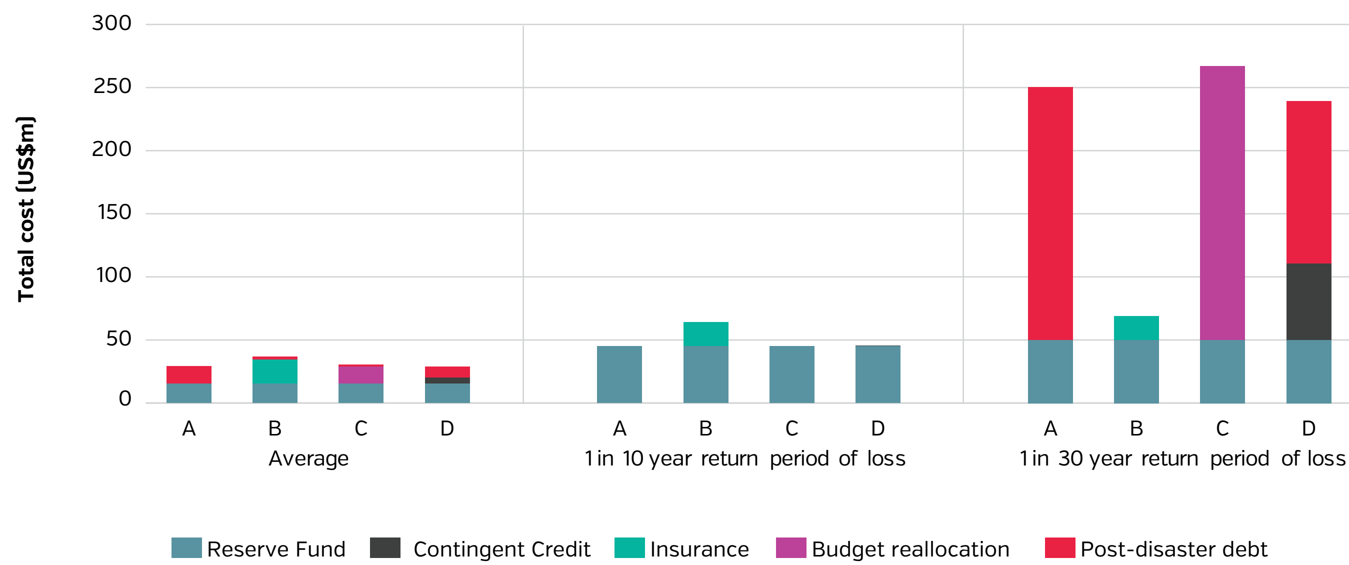
Figure AZ4.3 and AZ4.4 demonstrate the relative cost savings and overall costs of the four strategies over different return periods, assuming that the layers of non-insurance arrangements are doubled.

Figure AZ4.3 – Relative Cost Saving of Increasing Non-Insurance Layers



Source: Clarke, Cooney, Edwards, and Jinks (2016).

Figure AZ4.4 – Total Cost of Increasing Non-Insurance Layers



Source: Clarke, Cooney, Edwards, and Jinks (2016).

- In this sensitivity scenario, the average costs of Strategies A, C, and D increase slightly. This is because losses up to the 1 in 11 year return period are met by reserve funds which become marginally more expensive than post-disaster debt beyond the 1 in 7.6 year loss (see Figure AZ3.1).
- The average cost of strategy B reduces slightly, because there is a reduction in the premium payable, due to the higher attachment point (though this is partially offset by the higher equivalent pricing multiple that results from the assumed constant risk volatility loading).
- At the 1 in 10 year return period, the cost of Strategies A and C are identical because losses are met by reserve funds in both strategies. Although losses are also met by reserve funds in Strategies B and D, the cost is higher due to the contingent credit arrangement fee and insurance premium. For Strategy D, the difference is small; however, for Strategy B, the insurance premium means the cost is 42 percent higher than Strategy A.
- At the higher return periods, Strategy B continues to be the most cost-effective; however the cost savings of Strategy B relative to Strategy A are reduced. This is because losses up to the 1 in 11 year return period are met by reserve funds, which become marginally more expensive, and because it is less cost-effective to attach insurance at a higher level.

Glossary

Average	A number expressing the central or typical value in a set of data. In this report, average refers to the mean, which is calculated by dividing the sum of the values in the set by the number of values (data points) in the set.
Average Annual Loss	The average (mean) annual loss to a layer, calculated by summing all losses above the layer minimum and below the layer maximum in the relevant simulations and dividing by the total number of simulations.
Budget reallocation	The release of resources originally designated for a different purpose to cover costs associated with financing losses due to disasters considered.
Capital reserves	The funds held in respect of a potential contingent liability, typically held by insurers or any party taking on an element of risk.
Contingent credit	Financing credit available from a source to a recipient which is contingent on a trigger (for example, a natural disaster occurring), and for which the recipient pays a set-up fee as a percentage of the total credit available.
Contingent liability	A potential payment obligation that may be incurred depending on the outcome of a future event.
Cost / Opportunity cost	The cost of an alternative use of the finance that must be forgone in order to pursue a certain strategy. Throughout this report, references to cost imply opportunity cost.
Delay factor	The assumed cost increase due to delayed response. A delay factor of 1.5 corresponds to a situation where delayed response of US$1.50 has the same impact as US$1 of fast response cost. This delay factor is applied to financial or budgetary instruments assumed to be slow in situations where slow response is less cost-effective than fast response.
Ex-ante	Before an event – based on forecast results rather than actual results. For example, the ex-ante investment return is the expected return on an investment portfolio.
Ex-post	Subsequently to an event – based on actual results rather than forecast results. For example, the ex-post investment return is the known investment return that was achieved on an investment portfolio.
Hurdle rate	Rate of return on foregone investments, specifically considered in the context of budget reallocation. This rate is also used to calculate the (opportunity) cost of the insurance premiums that will need to be paid by government or development partners.
Insurance (risk transfer product)	An arrangement by which a company undertakes to provide a guarantee of compensation for specified loss in return for payment of a specified premium.
Insurance attachment	The trigger point at which insurance will start to pay, for example an insurance attachment of US$5m, means that losses that are smaller than US$5m would not trigger a payout from the insurance contract.
Insurance exhaustion (insurance limit)	The maximum point to which insurance will cover losses, for example, phrased as up to the 1 in 30 year loss or up to a loss of US$100m.

Marginal cost	The additional average opportunity cost of each risk finance instrument (such as, insurance) per unit of annual average loss, for losses at a specific return period.
Opportunity cost	The cost of an alternative use of the finance that must be forgone in order to pursue a certain strategy.
Parametric insurance	A type of insurance that does not indemnify the pure loss (that is, the pure response costs incurred), but ex ante agrees to make a payment upon the occurrence of a triggering event. This is common for natural disaster insurance where the trigger might be the severity of a windstorm or the magnitude of an earthquake on a Richter scale.
Pricing multiple	$\text{Pricing multiple} = \frac{\text{Premium}}{\text{Average Annual Loss}}$ A factor applied to expected losses by an insurance company to determine the premium required for the insured risk. This factor would reflect the cost of capital and expense costs of the insurance company.
Return period (of loss)	An indication of the likelihood of an event occurring; a recurrence interval demonstrating how frequently an event is expected to occur. For example, an event or a loss with a return period of 5 years is statistically expected to recur every 5 years on average over an extended period of time (or has a 20 percent probability of occurrence).
Risk finance strategy	A set of finance instruments combined to provide funds to cover the financial effect of potential losses.
Risk volatility loading	$\text{Risk volatility loading} = \frac{\text{Premium charged - Average Annual Loss}}{\text{Standard deviation of loss}}$ The factor applied to the chosen measure of risk (in this case the standard deviation) by the party accepting the risk (in this case insurers), in a set of simulated losses.

Disaster Risk Financing & Insurance Program

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